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THE WORLD OF FOSSILS

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BY

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ILLUSTRATED
BY THE AUTHOR

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PREFACE

Fossils may be considered in various ways. Taken merely as curios, they interest us for a moment but mean little; regarded as extinct organisms to be analyzed and classified, they tell a great deal to the specialist and almost nothing to the rest of the world, which is warned away by dry descriptions and too many long names. But when they are accepted as the remains of living organisms which had work to do, problems to solve and emergencies to meet, they become interesting to all of us—and yield to discussion without technicality.

It is such discussion that this book attempts, using fossils chosen from the animal kingdom. Ranging far beyond my own researches, it contains facts and theories borrowed from many sources to which no references are made. Yet I wish to acknowledge the debt, which extends also to maps and restorations. Though all have been specially drawn, the majority are based on the work of those men who have carefully studied the animals represented and the geologic records of earth evolution. Fortunately it has been possible to do what could not be done in the text: to indicate in parentheses the name of the man whose original figures

have been used in preparing each picture. I hope they will accept this slight indication of credit and forgive the changes introduced to meet the requirements of this book, or to incorporate my own ideas.

C. L. F.

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THE WORLD OF FOSSILS

CHAPTER I

HUNTING BIG GAME OF THE PAST

WHEN Thomas Jefferson rode to Philadelphia to become Vice President, in the spring of 1797, he took with him some bones from a cave floor in western Virginia. To the members of the American Philosophical Society, he read a memoir describing the specimens. It was published in 1799: the first study of American fossils by an American.

The bones were those of an extinct ground sloth, but because the skull was gone and the claws large and sharp, Jefferson thought the beast a gigantic lion which he named Megalonyx, or Great Claw. Nor did he realize that its whole race was dead, but suggested that some of the animals still lived in that "immense country to the West and Northwest," of which, he said, "Our entire ignorance . . . does not authorize us to say what it does not contain." That not alone Great Claw, but thousands of other animals, had lived, prospered and become extinct was a fact that many naturalists of 1800 did not perceive.

✓Yet fact it was; and every new discovery of buried bones and shells made it more plain that the earth once supported forms of life not upon it to-day. Only by finding and studying their fossils could the lives and

ways of these ancient creatures be determined, and the whole history of life be written.

But before we go on, what is a fossil? Briefly, we may say that it is either the remains or trace of an animal or plant that lived in past geologic time, and was buried in the rocks of the growing earth. It may be a

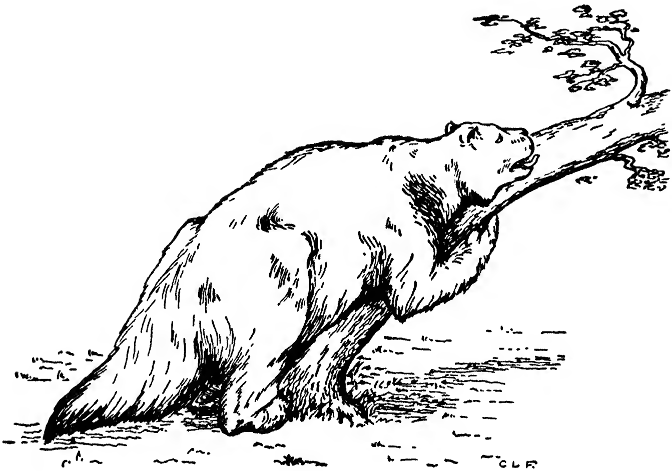

FIG. 1.—JEFFERSON'S GROUND SLOTH, *Megalonyx jeffersoni.*

petrified twig, shell, or even skeleton; it may be only an impression or footprint in a layer of stone. Whatever it is, it tells a story of life in vanished ages—a story as interesting and important to us as that inscribed upon any tablet of Babylon, or in any mildewed medieval manuscript.

It is to recover this story, now buried in the rocks,

that museums and other institutions send out expeditions and collectors whose chief duty is to hunt for fossils. Sometimes, of course, they need not go far from home, for there are many ancient animals whose remains lie in the midst of our modern civilization. In the city of Cincinnati, for instance, one may pick up fossil bryozoans—the name means "moss animals"—in almost any vacant lot. In Chicago, we find fossil corals and snails in quarries where huge rock crushers are breaking stone for use in pavements and the foundations of skyscrapers. Almost in the shadow of Minneapolis' flour mills lie shells of clams, buried where they lay on a muddy sea bottom, hundreds of millions of years ago. And in Iowa the farmer drives his sleek team or gray Fordson over solid beds of sponges and corals. No, the fossil hunter does not have to go into far places of the earth when he wants to find things that are old and strange.

Of course, sponges and corals are not very large game, and the regions where they are found do not often hold the remains of huge land-dwelling animals. Even though the bones of the queer elk-moose have been found in Iowa pastures, and the tusks of mastodons in what were to be the basements of apartment houses, the majority of ancient monsters are less conveniently buried. The bigger and stronger dinosaurs, the six-horned Dinoceras and the swamp-loving rhinos —these and many lesser beasts whose bones are still queerer than their names, must be sought in places which even to-day are not too civilized. Hunting them

is as much of an adventure for us as is a trip to Africa in search of lions or buffalo. The thrill that comes from danger may be lacking, but in its place is the one which comes with the hope of finding something new, that no one else ever has seen.

Yet in these hunts for big game of the past there are some hardships, some dangers. An expedition working in the desert must have food and water; hunger is no more fun to-day than it was when Richard the Lion-hearted was king. Rattlesnakes are averse to fossil hunters as well as tourists and are much more apt to be disturbed by them. A ten-ton block of limestone can kill one quite as dead as can an elephant and will make less noise while doing so. And if the fossil hunter encounters nothing quite so terrible as traffic on Broadway at 5:15, it is because his quarry has lain buried too long to begin stampeding.

Yet there was a time when fossil hunting was dangerous—the time, fifty to seventy years ago, when pioneer scientists were pushing their way into the still wild West. Much of the land belonged to hostile Indians, who could see no difference between a scientist and a settler except that the former's queer actions made him even more suspicious. Expeditions traveled by horse and wagon over roadless country; and since only the most essential things could be carried, they, like the tribesmen, "lived off the land." The well-equipped expedition of the sixties carried more guns than pick-axes, and soldiers often outnumbered scientists. Even though the Indians might be unwilling to fight, they

generally were ready to steal or to threaten. The journals of early collectors often tell of supplies and horses spirited away, and there are at least a few authentic accounts of skirmishes with hostile Indians. The historian of the past in those days was a hunter in more ways than one—and he might be the hunted as well.

To-day, of course, times are changed. Sons of chieftains who fought the paleface nod—and smile—while paleontologists tell of animals that lived ages before the Manito made bison. In Mongolia, tribesmen build their shrines of empty gasoline cans, drained by fossil-laden trucks, and pull hair from camels to furnish packing for delicate specimens they have helped to find. Natives of India dig up the bones of extinct mammals and must be watched only because tradition may cause them to destroy what they so carefully uncover. If there is danger to-day, it threatens the specimen rather than the man who collects it.

For a fossil bone, even though it has withstood the passage of millions of years, may be destroyed by a few minutes of careless handling. Those early expeditions, heroic though they were, brought back hundreds upon hundreds of fragments which cause untold trouble to cautious scientists, and furnish fine examples of what shouldn't be done. Of course, it may be possible to reconstruct a rhino or saber-toothed cat from a few broken bones and teeth; but the fewer they are, the poorer the reconstruction. Dozens of the scanty remains brought in by early workers mean worse than nothing to-day. They can't be recognized,

and they can't be ignored; if we try to link them with new discoveries, our conclusions may be either right or worthless. Often the very specimens that might have settled such problems were thrown aside half a century ago because methods were not known by which they could be rescued. Museums realize this, and so they make every effort to equip their parties for work so careful that nothing worth saving will be discarded or spoiled.

Thus it is that modern expeditions have come to be affairs of administration and plan, not mere hunts. Yet despite this change, there are all kinds and sizes of them. The simplest consist of two or three men in a second-hand car, into which is loaded tent, outfit and tools for a summer's work. At the other extreme stand such ventures as the Third Asiatic Expedition of the American Museum of Natural History, with a staff of scientists, photographers, technicians, artists and laborers, and an array of "rolling stock" which ranged from specially built trucks to long trains of camels. Yet even this, the finest expedition ever sent out, rested upon the same essential basis as do the two-men-and-a-flivver parties which go out each year from colleges and museums throughout the land.

For the real foundation of a hunt for fossils is neither equipment nor money. It is purpose: the purpose to bring back to civilization the best possible specimens representing the life of past ages. To accomplish this, every collector does his work with skill and care undreamed of by those pioneers who had to keep

one hand on the pickax and the other on a rifle. Methods have changed with the times, and to-day even the beginner may be a specialist.

This specialization has more to do with collecting (and studying) the specimen than with finding it. Fossils are sought to-day much as they were half a century ago: by looking in places where precept and experience give hope of success. There also is a good deal of luck, and what we call intuition; no good collector can tell you just how and why he found every specimen. But to dig it out without spoiling it, to pack it so that it could be shipped thousands of miles in perfect safety, to clean it so that it suffers not the slightest injury—these are tasks in which luck is an enemy and only cautious care can win.

Let us pause for a moment to watch a collector who has found a fossil that he thinks is worth digging out. If a skeleton, it probably is buried so deeply in rock that only the tips of a few bones are visible. To get at it, he first uses a pick and shovel; if the rock covering is very thick, he may employ dynamite and horses as well. Or he may go even further; for in Cleveland a few years ago, an ambitious museum put a steam shovel to work digging out fossil sharks, getting more specimens in a few weeks than a man would gather in years of labor with pick and chisel. Of course, those sharks were exceptionally well protected by stone, or they would have gone to bits under such treatment.

Even during his roughest work, the collector must

FIG. 2.—BONES OF A PERMIAN REPTILE, IMBEDDED IN ROCK.

remember that the prize may be as delicate as it is old. He must know just when to drop his pick and use a trowel; when to lay the trowel aside and apply scraper

and camel's hair brush. At the proper stage, he traces the limits of the specimen and trenches around it; if the specimen is large, he then cuts the rock away from beneath the block of rock containing it. Meanwhile his assistants (if he's so lucky as to have them) have built a block and tackle derrick, with which they can lift the mass of rock from its pit and set it out for packing.

That is, for final packing, since the work of covering and strengthening the bones begins as soon as they are revealed. As bone after bone comes to light, it is soaked in gum, mucilage or shellac, with rice or tissue paper to coat its surface. If cracks appear, they are reënforced or mended, and supports take care of every strain. No fractured limb receives more careful treatment than that which a good collector gives to a valuable bone.

And indeed, what follows strongly suggests surgical treatment. Just as a surgeon applies a cast to a broken limb, so the collector dips strips of cloth in wet plaster and presses them against his fossil bones, crossing and recrossing them until the whole mass is supported and covered. If it is very large, he adds splints of wire, wood or strong iron, so that the specimen cannot twist or "wrack." Then, and only then, can it be boxed and made ready for shipment.

Once the box reaches the museum, all this complex wrapping must be removed, along with the rock which was left untouched. Bones crushed into tiny fragments are pieced together, strengthened with brass or

steel, and eventually assembled into the impressive skeletons which appear so often in illustrations of books. Or perhaps the process must be reversed: in order to learn details—tremendously significant details—of structure, bones originally united must be taken apart.

This happens most often with the bones of the skull, on which much of our classification of animals is founded; and the results achieved often are astounding. Imagine a skull, millions of years old, and so delicate that its petrified bones are almost transparent—yet taken apart as you or I might separate the bones of a horse or alligator! Yet that is what I saw one day in New York, while the man showing it remarked: "This, really, was pretty simple, since the bones in it weren't badly crushed. When I get through, maybe I'll tackle some of those other things, which really are badly damaged."

I looked at the "other things," which seemed mere masses of fractured bone, and thanked fortune that mine is the comparatively simple job of putting Latin names on fossil shells and corals.

CHAPTER II

FROM SEA MUD TO MOUNTAIN

WE have said that a fossil is the remains, impression or even the trace of a plant or animal that lived during some past part of the earth's history. It was preserved by burial in the rocks, which from time immemorial have been accumulating on our planet's surface. And there it stayed until accident, whether in the shape of rain, river, or learned collector, dug it out of its stony grave.

The fossils which cause collectors greatest concern are those which are large and in many pieces. It is these which require the elaborate methods that we have just reviewed; and they are the ones of which we read most often in magazines and newspapers. Thanks to them, and to the movies, dinosaurs, pterodactyls and mastodonts have become parts of our everyday existence.

These animals, like most others that come to mind when the word fossil is mentioned, belong to the vertebrates—animals which possess skeletons. They interest us because so many of them are strange as well as large, and because others are more or less like the animals which we see in cages at the zoo or circus. As a result we give them a great deal more attention

than they actually deserve, for in reality they form a rather small part of the record of life. Many students of fossils live lives that are long, happy and useful without ever bothering to examine those ages in which vertebrates become abundant.

If numbers counted instead of size, the smaller, shelled animals of the seas would deserve the lion's share of attention. They lived and died ages before the first vertebrate wiggled in search of food; they continued throughout other ages in which the highest backboned animal was a soft-skulled fish. Even when fishes took to land and developed legs, the animals of the seas went comfortably on, and their fossils to-day outnumber those of vertebrates by millions to one. A good collector of dinosaurs or elephants may work a lifetime and find but a few hundred skeletons and important bones; the collector of fossil shells or corals may get thousands in a day if he knows where to look for them.

Thousands? Yes, and many of them. One day, years ago, I knelt on the clay of an Iowa roadside from seven in the morning until six at night, gathering the inhabitants of a sea that vanished three hundred million years ago. At first I tried to pick the specimens up one by one, but they were too many. Then I brushed them into little heaps, like a fairy-book miser with his piles of gold. But that also was too slow, and missed the smallest ones. So I took a brush and swept them onto pieces of newspaper—and my total finds numbered more than ten thousand specimens. I

have visited that roadside many times since, but have not had courage to try a count of the specimens collected from it.

But not merely are marine fossils more abundant than the remains of land or even freshwater animals and plants; many of them are vastly older. The very earliest animals that have been discovered are distant relatives of crabs and lobsters—undoubted dwellers of the sea. Even the fossils of that Iowa roadside were more ancient than any terrestrial vertebrate, although they did include teeth of a few fishes. Were we interested in plants, the contrast would be even greater. No one can guess when the first one-celled alga began to live, but its descendants were building great banks in seas from which no animal is known. There were giants in the plant world before the family tree of the vertebrates even took root.

Another interesting fact about the inhabitants of ancient seas is this: though many of them are unlike anything on earth to-day, their general appearance and habits must have been surprisingly like those of animals living in the waters of modern bays. This is true even of the vertebrates; it is much easier to compare fossil sharks with living ones than to compare Brontosaurus with a lizard. Among shelled animals without backbones, the resemblance is even more striking, and it may be seen even in the sponges and corals. Often it is the result of real kinship. Kinds, or species, are different, of course, but there are several of those larger groups called genera which seem

Eras	Periods		Mountains	Life	Years Ago
Cenozoic	Quaternary	Recent		Age of Mammals	
		Pleistocene			2,000,000
	Tertiary	Pliocene	Alps		
		Miocene			
		Oligocene			35,000,000
		Eocene			
		Paleocene			60,000,000
Mesozoic	Cretaceous		Rockies	Age of Reptiles	100,000,000
	Jurassic		Sierra Nevada		
	Triassic				205,000,000
Paleozoic	Permian		Appalachians	Age of Coal Forests	
	Carbon-iferous	Pennsylvanian			
		Mississippian			300,000,000
	Devonian		Scotch Highlands	Age of Fishes	
	Silurian				400,000,000
	Ordovician				
	Cambrian				600,000,000
Proterozoic	(Not Named)		Young Laurentians	Age of Algæ	1,200,000,000
Archeozoic	(Not Named)		Early Laurentians	Appearance of Life	1,800,000,000

FIG. 3.—THE GEOLOGICAL TIME SCALE.

to have survived almost without change since they first saw the dim, rippling light of Paleozoic seas.

It is this kinship in type and descent among fossil and modern sea-dwellers which makes it so easy for us to picture them in the surroundings amidst which they lived. When such pictures contrast with modern ones of city and factory, built upon the very same spots, they help us to realize the extent of the changes that time has wrought on the face of the earth.

Let us suppose, for the moment, that we are in Cincinnati. Each morning we ride from our homes on the hills to offices and factories in the deep, narrow valley of the Ohio River. Every foot of the way, we travel over one-time sea beds whose rocks contain the remains of animals whose habits must have been like those of creatures now living in the North Sea, off the Massachusetts coast, and in Puget Sound.

In the shales and limestones of the hillsides lie fossil clams that might have made chowder, had there been any men to dig and cook them. There are shells of snails—snails that look so much like periwinkles of the Atlantic that we exhibit them side by side. Certain other snails ate the clams by boring holes in their shells, just as the moon snail and oyster drill do to-day. Fossils have been found in which these borings are preserved—though most of them are in other kinds of shellfish, called brachiopods, whose relatives are common to-day in the shallow waters of Puget Sound and on the coasts of Japan. Other brachiopods doubtless were eaten by starfish—but unfortunately, we can-

not recognize the victims. The starfish themselves are rare, and a good deal more primitive than any living to-day, but there can be no doubt of their relationships and habits.

Upon the shelled animals, and in independent clumps and branches, grew the bryozoans—animals that looked a good deal like corals and a little like mosses, yet really were related to neither. Some of them grew in complex, branching colonies which sheltered many small animals that neither could build homes nor defend themselves from attack.

Waving gently above the mud on which these creatures lay or crawled were groups of sea lilies, or crinoids. Each crinoid looked something like an Easter lily without its leaves, and with fringed instead of simple petals—yet it actually was a cousin of the starfish which in the distant past had turned itself upside down and had grown a long, stemlike column. Among these columns wriggled sea worms, doubtless just as brightly colored as any of those which to-day crawl on the Cape Cod shore. Finally, there were the trilobites, ancient forerunners of the crab and lobster, whose purplish brown shells lay here and there in the soft mud, or crawled clumsily about in search of food.

Such was the population of the Cincinnatian sea during the closing centuries of the Ordovician period, perhaps four hundred million years ago. With slight changes, the picture can be made to fit other sea bottoms in New York, Ontario or Minnesota. With greater modification, it suggests the faunas of much

later ages as well; for as we already have seen, the important groups of marine animals have changed very, very slowly.

But how, one may ask, does it come about that animals so small as some of these are so well preserved? And what has happened to turn the soft muds of shallow sea bottoms into the firm rocks of prairies, hills and even mountains?

Much of the answer lies in the fact that the muds were deposited in *shallow* seas. Therefore they couldn't be very far from shore, and from that shore new stores of mud were coming daily. Scarcely had a clam, a crinoid or a trilobite died, when tiny particles began to cover it, sealing it in a layer of protecting ooze. There it lay while the waters that so promptly had buried it began to dissolve particles of shell, and leave other particles of mineral matter in their place. With the passage of centuries, the remains became fossilized—and petrified as well.

Of course, not all marine corpses received such fine treatment; a shell that died and fell among sands was apt to have a hard time of it, while one among gravel had no chance at all. Those animals buried in mud were the most fortunate, and some of their remains include not merely bones or shells, but traces of skin, muscles and even delicate organs within the body.

Since these creatures lived and were buried beneath shallow seas, there was not a great deal of water over them in the first place. A slight change could remove it entirely. The sinking of an ocean not far

away, or an upward warping of the sea floor, was quite enough to turn the haunts of sponges and trilobites into land. In some cases it was the water that withdrew; in others the rock bent or thrust itself upward, lifting the sediments and their fossils even into plateaus and mountains. Where such uplift has been greatest: where it has brought not merely a few hundreds, but, ten, twenty or even thirty thousand feet of rocks up from the depths beneath the sea—there we find the most ancient of all formations prominently displayed. In other places they may be deeply buried, or worn down to lowlands; but in mountains they stand out boldly, while the beds once above them are worn away.

This is why fossil hunters, when they seek ancient specimens, so often go to the mountains to find them. That is what Mrs. Fenton and I have done in our hunts for early plants in the Montana Rockies. Our camps were pitched almost a mile above sea level—and though that may seem low to people who live in Colorado, it still is a height at which sea plants never grow. When we set out to collect, we had to go still higher, through flower-filled valleys that turned even hardened paleontologists into amateur botanists. Leaving the valleys, we continued to climb: ten, twelve, or fifteen hundred feet in order to reach the strata containing those plants whose home in life had been wave-washed mud flats.

One day, after climbing two hours, we still found ourselves at the foot of a steep wall whose crest was

the bed that held our fossils. So up we went for another thousand feet, over the mud cracks and ripples of vanished shores. At the top we dropped our bags and hammers, to scan the cliffs for still higher layers that might have fossils.

As we looked, something moved—something white and shaggy, with short black horns. It was a mountain goat watching our intrusion into his home. It flashed upon us that there, on that mountain wall, we had the high points in the history of life. At our feet were fossil algæ, so old and so primitive that some authorities think them nothing but rocks. Above us was the mountain goat, most modern and specialized of all the animals that dwell on alpine peaks. Between them stood ourselves, members of a race that has learned to dive to the bottom of the sea, and to fly above the highest peaks. Yes, the high points in the story of life—the story that we were doing our bit to unfold.

CHAPTER III

THE TALE OF TRILOBITES

LET us, in imagination, don divers' helmets and visit the bottom of an early sea whose waters lay where the cliffs of Mount Wapta now rise, above the little railroad town of Field, British Columbia. On the way, we shall travel (backward, of course) through several geologic ages to the middle portion of the Cambrian period, some five hundred million years ago.

The sea that we reach is one which stretched northward and southward for hundreds of miles, in the region of the present Rocky Mountains. Its waters were shallow and generally quiet; into them flowed silt-laden streams from lands to both east and west. As often happens in shallow marine basins, both plants and animals were present in abundance, their remains being heaped in those sheltered pools to which currents might roll or drift them.

As we look at the array of creatures gathered in these pools, or scattered about the muddy bottom, we notice seaweeds of several types, glass sponges, shells, and crawling, brightly colored sea worms. Animals that look like shrimps dart here and there through the water; crustaceans with the forms of clams put

out jointed legs on which they crawl. Movement among the dead fronds and bodies show where burrowing scavengers are at work, prying through rubbish in search of meals.

More striking than any of these, however, are animals which suggest flattened, flexible crabs, or small lobsters whose pincers have been lost in battle. Each has a large head bearing two smooth, greenish, faintly glowing eyes. From the head, long antennæ project, waving to and fro as the animal crawls; behind it is a body made up of joined segments which only partly cover the jointed legs beneath, of which one pair match every segment. The tail is little more than a small button that finishes the tapering body.

This queer creature is Neolenus, best known of all Cambrian trilobites. He belongs to a class from which the crabs, lobsters, scorpions, spiders and other jointed-bodied animals have sprung; though not the simplest, he is fairly typical of the early members of his kind. Like many famous ancestors, he is neither very powerful nor very handsome—yet he is one of the leading citizens of the Wapta sea. Only one of his neighbors is able to attack him, and that is a crab-like cousin whose powerful pincers can break even a trilobite's shell.

The habits of Neolenus are just what one expects from a creature of his general connections and form. When very young, he floats in the water; but as he grows in weight and dignity, he settles down to a crawling life, eating defenseless or dead animals that

FIG. 4.—A CAMBRIAN SEA BOTTOM, SITE OF MOUNT WAPTA, BRITISH COLUMBIA.

In the foreground, the trilobite *Neolenus;* behind it, a clump of plumed seaweeds (*Marpolia*) and a relative of the scorpions. At the left, shelled crustaceans, glass sponges, seaweeds and swimming molluscs. Two shrimp-like forms are swimming above, while worms crawl on the more distant mud.

he can find on the sea floor. His antennæ help him to discover food, and his many legs take him to it promptly. About the piles of carrion gathered in the pools a dozen or two trilobites may gather, each busily eating such of it as is edible.

Like his descendant, the crayfish, Neolenus can grow only occasionally. Month after month he goes about in a hard, hole-proof shell or "test," within which his body is imprisoned. Then, one day, a slit appears at the front of the head—and with much wriggling and twisting, our trilobite begins to molt. Each effort pulls his body farther out: until in the end, he emerges as a softer and larger creature, which must hide from his enemies until his new covering has had time to harden. Once it has done so, he is again confined and protected and may resume his business of prowling for carrion.

This habit of molting explains why fossils of trilobites are so very common, yet often consist of mere fragments. Unlike some reptiles, Neolenus does not even try to eat his discarded skin. He leaves it lying on the mud, where it slowly falls apart and is buried. Thus one single covering makes many pieces, each of which may become a fossil; and since there are many molts in the growth of one trilobite, his fossils may be numbered in dozens, only one of which can be his dead body.

As he crawls about on the muddy bottom, Neolenus is bound to meet some of his relatives. The most abundant ones are small: little, smooth fellows half

an inch in length, with tails at least as large as their heads and only two body segments. One of them

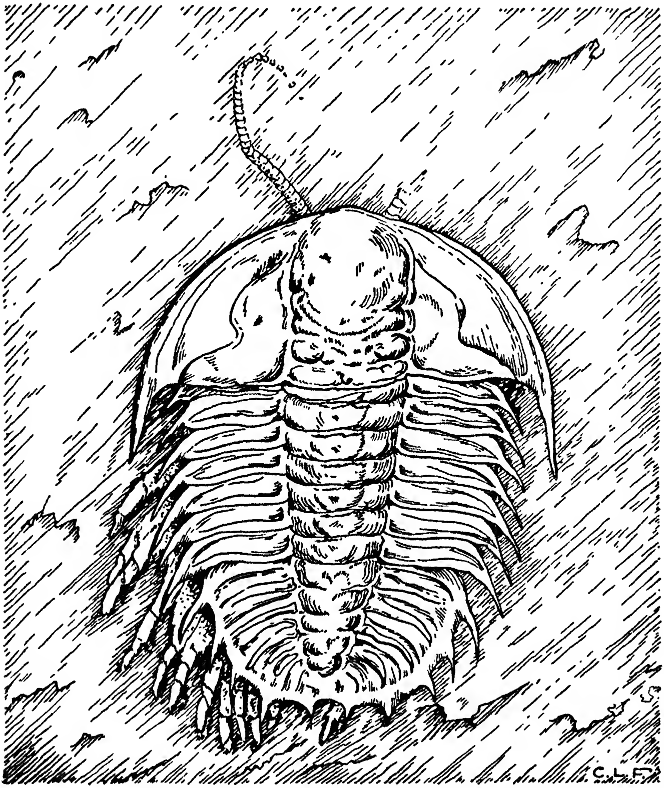

FIG. 5.—A CAMBRIAN TRILOBITE, *Neolenus,* IN A SLAB OF BLACK SHALE.

has tiny eyes; another (Fig. 8C) is completely blind, and spends his life burrowing among the bodies of

dead plants and animals, or plowing the mud in search of food. He is the smallest, most specialized of his kind—and the degree to which he differs from Neolenus shows how far the race had progressed at the beginning of its fossil record.

Concluding our hasty trip to the past, we discover how great the trilobites became—how varied were their forms and habits. They appeared at the very dawn of the Cambrian, as many-jointed forms that moved by crawling. Few were dwarfs and none were giants, while the majority were what we call "generalized types"—which means that they are best known by their specialized descendants.

Some of these, as we have seen, lost eyes and segments, spending their lives beneath Cambrian sea bottoms. Others did not burrow so deeply: plowing to and fro in the mud, they managed to meet their simple needs. When danger threatened, they rolled into balls, their round heads and tails making a perfect armor. No armadillo can do as well, while turtles are less completely covered.

Many trilobites of the Ordovician seas managed to live even more simply. Digging into the mud with their spade-shaped tails, they buried the hinder part of their bodies and lay with their mouths just at the surface. They depended on food that drifted on the sea floor; and if the supply was not always abundant, they were too inactive to need much to eat. That is

the great advantage of being lazy, as many races of animals have discovered.

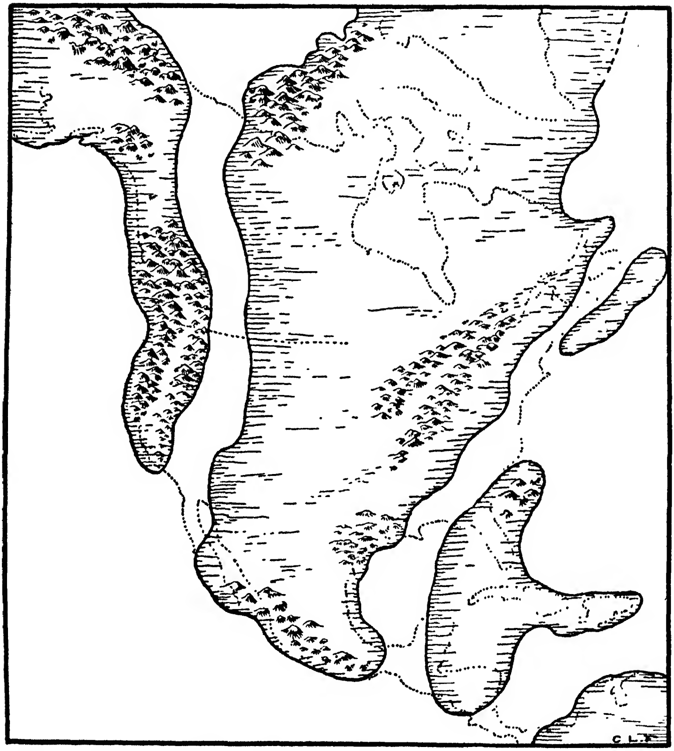

FIG. 6.—NORTH AMERICA DURING EARLY CAMBRIAN TIME. (SCHUCHERT)

Other Ordovician trilobites had large, round heads and huge, compound eyes, which quite overshadowed their weak bodies. Thus they resemble some fishes

of ocean abysses; but their remains are found in the sediments of shallows. Probably they were night feeders, that hid in dark corners by day, and came forth in the evening to find mates and food. Thus their enormous eyes were of use, while their poorly protected bodies were tucked away during the hours when enemies most easily might hunt them.

Other species, especially during the Silurian period, had small bodies whose shells bore long, sharp spines. Some of these may have crawled about the bottom; others found themselves caught by currents in the water, and thus drifted about with but the slightest of effort. The smallest ones probably lived among tangles of seaweed, where their spines helped them to maintain their foothold and served as protection against attack. Marine carnivores may be stupid: but they are not too dull to recognize pain, and to keep away from things that inflict it.

Let us glance at a sea in which the large spiny trilobites reached their zenith. It stretches from Maryland to New York in the early Devonian, or Age of Fishes. Its most conspicuous animals are crinoids, animals closely related to starfish, yet with forms so plantlike that their common name is "sea lilies." Below them wave brown and green seaweeds, while the muds are dotted with clams and lamp shells. What seems to be a miniature porcupine turns out to be a carnivorous snail, feeding upon the flesh of a clam into which its tongue has bored. Among the plants,

a pinkish animal in a frilled shell is struggling with a partly coiled trilobite.

Yet his neighbors in the foreground are not much disturbed. One, whose eyes are faceted like those of a fly, pokes a spined snout among the green seaweeds, and bears another long spine upon his tail. Near him

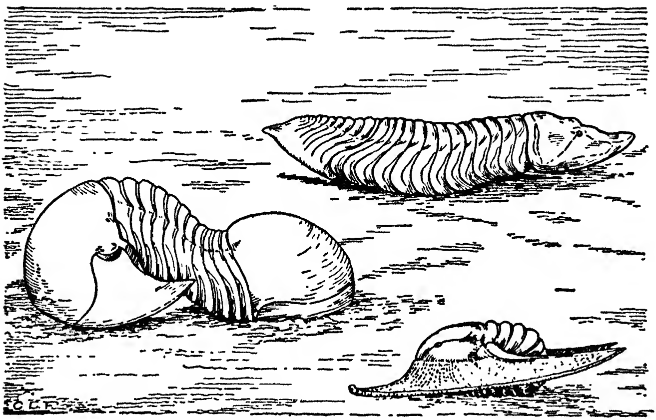

FIG. 7.—TRILOBITES: TWO CRAWLING FORMS THAT ALSO BURROWED, AND ONE ENROLLED FOR SAFETY—ALL OF SILURIAN AGE.

is one with a rounded knobbed head, knobs and spines scattered over his body, and a lobed, knobbed and spiny tail. Though appetizing flesh may lie beneath that armor, no hungry marauder is apt to desire it while less prickly prey is to be found. Even the snail, itself armed with spines and a rasping tongue, feeds upon the smaller—and smoother—clams.

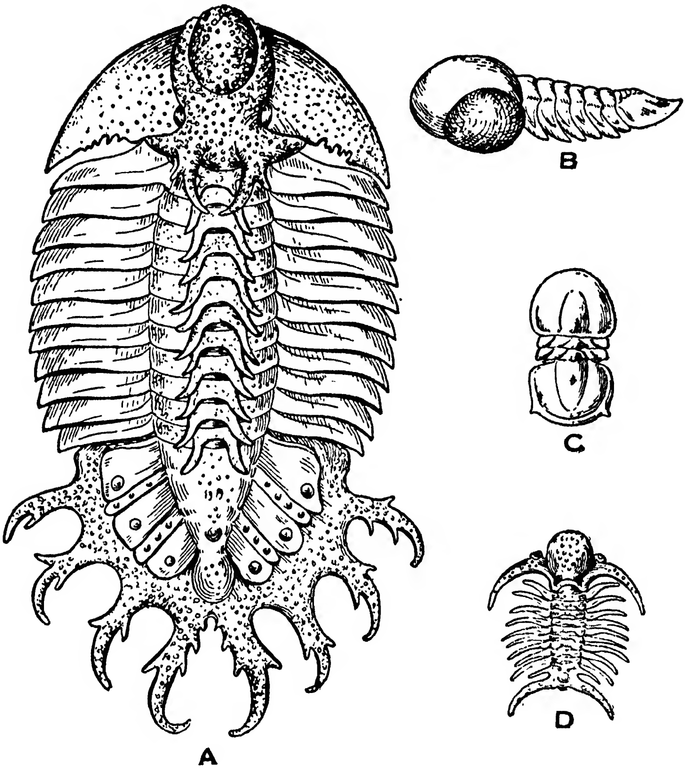

FIG. 8.—SPINY, BURROWING AND PELAGIC TRILOBITES.

A, the giant Devonian *Terataspis;* B, the large-eyed, nocturnal *Aeglina* of Ordovician age; C, the blind Cambrian burrower, *Agnostus;* D, the Silurian *Deiphon,* which hid among seaweeds.

Yet even this species scarcely compares with the green giant beneath the crinoids (Fig. 8A). His eyes are shielded by a central helmet at whose back

rise two pairs of curved spikes. Another pair projects from each segment, while the tail is ridged and plated and set with eight long, barbed spines. Terataspis is the largest of spiny trilobites, with a length of twenty-seven inches. If mass and armor mean much, his life is immune from ordinary dangers such as threaten smaller, defenseless animals.

Yet protection does not give immortality. By the time that land plants first became common, trilobites were growing rare. The spiny forms already had vanished: those that survived were small and plain. Even they became fewer and fewer, in species as well as in individuals. By the end of the era that saw them appear, the race of trilobites was extinct.

What does extinction mean, in a group once so abundant and powerful? Conclusions must be drawn with caution, since the events took place so long ago. Yet this much, at least, seems certain:

Extinction, which finally overcame the trilobites, did not wait for the end of an era. It took place again and again, in the Cambrian as well as in later periods. Old forms gave way to new; these in turn were replaced by others, or surrendered their place to new kinds of animals. However safe they seemed for the moment, the most specialized forms were the first to vanish. The blindest burrowers, the most delicate floaters, the spiniest crawlers—these were the ones that first sank to extinction, while their more generalized neighbors survived.

Nor can all blame for the trilobites' destruction be

transferred to their surroundings. Individual seas might shallow or vanish, but seas themselves always remained. In them, such associates of the trilobites as clams, corals, snails and sponges managed to survive and prosper. A genus of lampshells (brachiopods) that appeared with the Cambrian lives, slightly changed, on modern seashores. It found existence difficult, perhaps, but not impossible; and therefore it lived while the trilobites died. Had they been endowed with the vigor of the brachiopod Lingula, they too might have survived. But they weren't, and for the lack that was inherent in their bodies, the environment hardly may be blamed.

CHAPTER IV

WHAT HAPPENED TO HORN SHELL

AMONG the swaying seaweeds of that Devonian pool, we saw a large shell, coiled and frilled, and striped with brown. From it extended an animal engaged in a bitter struggle with a partly coiled trilobite. The mottled, pinkish body, staring black eyes, and long tentacles provided with suckers, made it resemble an octopus or devilfish whose body was hidden within the shell.

As a matter of fact, it was a distant relative of both those animals, and a much closer one of the pearly nautilus, whose shell is described in more than one poem. All were—and are—members of the class of cephalopods, whose name means "head-footed ones," since in fitting themselves into their shells, they have so twisted their bodies as to make head and foot almost the same. Second cousins to the snails, they are both the most highly developed and the least successful of their kind, for comparatively few of them are alive to-day. Yet they once were the most abundant of molluscs, and the largest shelled animals of the seas.

Though the shell on that early New York sea floor has lain fossil for more than three hundred million

years, it does not belong to a primitive cephalopod. To find one of these, we must search vastly older strata: those representing the latest centuries of the Cambrian, and the early epochs of Ordovician time. In them we shall discover what, though not the first,

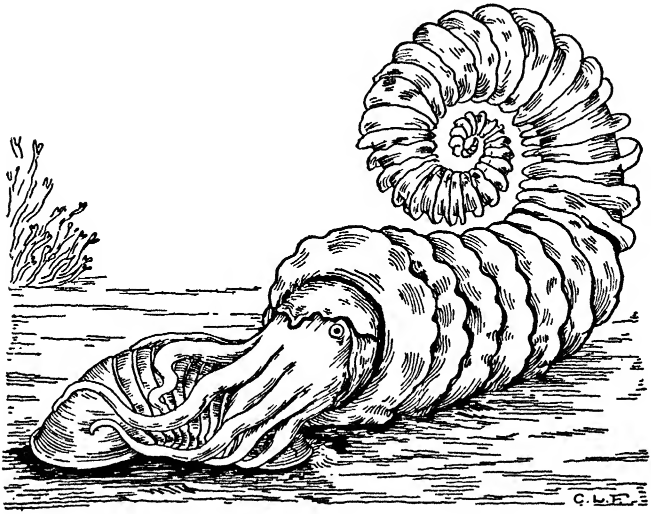

FIG. 9.—A FRILLED AND COILED CEPHALOPOD (*Rhyticeras*) CAPTURING A TRILOBITE. (RUEDEMANN)

at least are very early "horn shells"—and hence are the structural ancestors of all that have followed.

These simple shells are not really horn-shaped. They are long and straight, in the form of gently tapering cones. If we break one of them open, or look at a natural section in the rock, we find that the cone is made up of a great many sections or chambers,

each separated by a layer of shell. Through the center runs a long, segmented tube which is thin in some species and very thick in others; while the broad end of the shell is a single large chamber, in which the body rested during life. Figure 10A shows one of these shells in section; in life it held an animal like that of Figure 9.

The earliest cephalopods were small and smooth: their name, Orthoceras, means "straight horn." But as time passed, their descendants grew larger, until in mid-Ordovician seas that covered Illinois and Iowa, there were cephalopods with shells ten or twelve feet long. Others were flattened or wrinkled, or developed ridges and rings. All, it seems, were decorated with bands or patterns of color, some of which survive upon the fossils.

Since animals generally are darker above than they are beneath, these preserved colors seem to show that the typical Orthoceras spent a good deal of its life lying on the bottom, waiting for the approach of prey. Now and then, it crawled about by means of its tentacles; but when it really wanted to travel, it did so by sucking water in through a tube and forcing it out of another, violently. Since these tubes were located on the head the ejection of water shot the animal backward.

Or it would have done so were it not for the shell. That structure, despite its size and occasional beauty, must have been a great nuisance. If filled with gas, it bobbed to and fro behind the body, making direct

progress difficult. If weighted down by a thick central tube, it lay heavily upon the bottom, blocking rapid movement, and battering into whatever was in the way. Even though there were no streets to cross, autos to dodge or elevators to enter in the life of an Ordovician cephalopod, that long shell must have been a nuisance. Many a fossil shows injury to the empty chambers, while some seem to have been broken off during life, to the great convenience of their builders and owners. Although the suspicion cannot be proved, it is probable that the clumsiness of the biggest shells helped bring their makers to extinction.

At least, a premium was placed on any device that would shorten the cone and keep it up out of harm's way. The chance was grasped in various ways: some animals developed short, egg-shaped shells, in which they drifted bottom side up above the sea floor (Fig. 10B). Others crawled, with their short shells turned upward—and most of those shells were curved (Fig. 10C). In the course of time, curves gave way to coils, and the coils became closer and closer. In the process, the shell was flattened and compressed, but that seems to have caused no difficulty. The important thing was that the animal could keep on building chambers as it grew, without gathering a burden of clumsy, delicate cone. With this change, there is a striking decrease of shell fragments in the fossil-bearing rocks, and few of the coils record injury. Change was not merely a convenience: it cut both accident and death rates in the world of cephalopods.

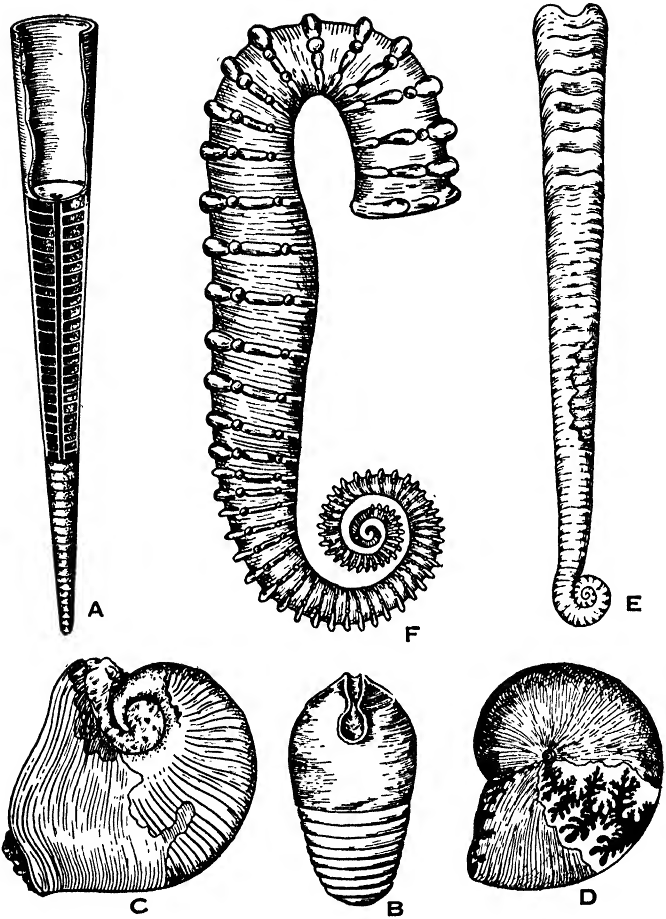

FIG. 10.—TYPES OF CEPHALOPODS.

A, *Orthoceras* sectioned to show living chamber and septa; B, a shortened Silurian form with narrow opening; C, a partly coiled Silurian species; D, an ammonite with one chamber blackened to show the complex septal crumpling. E and F, partially uncoiled types, *Lituites* of the Silurian and an aberrant ammonite.

This closely coiled type of shell is found in hundreds of fossil species as well as in the four living kinds of Nautilus. It must have been successful, since it has survived much more elaborate types—yet scarcely had it been established when some species began to abandon it. Strangely, however, they seemed unable to do so at once; each went through the whole ancestral series before it at last began to uncoil. In earliest stages, the shell was straight; then it became curved and loosely coiled; finally it passed through the Nautilus state, and then became straight once more. Yet its straightness was not that of the primitive Orthoceras, for unlike that simple but persistent form, these soon declined and vanished. Lituites (Fig. 10E), is one of these unfit types.

Yet theirs was only a minor tragedy. Coiled shells continued to develop, and from them sprang a new group which for ages threatened to obscure all others. They were the Ammonites—horns, men once thought, of the Greek god Ammon (Fig. 10D).

The most striking feature of this new race is neither their abundance nor size, but the remarkable complexity of their shell chambers. The partitions, or *septa,* which divide Orthoceras are simple affairs, shaped like watch glasses, each the size of the shell which it fits. Those of Nautilus are a little larger, yet even they bend smoothly in the whorls. But the septa of Ammonites are much too large for their flattened shells, into which they must be crowded. The result is like that which follows the stuffing of a large

sheet of paper into one's pocket. The paper is crumpled and so are the septa, whose wrinkled edges make irregular lines where they join the walls of the enclosing shell.

Yet the comparison is not perfect. Two sheets of paper will not crumple alike, but two or two thousand septa will. The irregularities upon them are surprisingly permanent; they serve to mark species and larger groups, and tell how far their owners have advanced from smooth, simple Nautilus ancestors. Early in Ammonite history—when the race was just being developed—the lines made by septa were relatively simple, but during the Age of Reptiles or Mesozoic era, they became almost unbelievably complex. One might say that the greater the crumpling, the more ornate the shell, the better was the Ammonite that built it—were there not one disturbing factor.

We have met that factor before in Lituites, the shell that indulged in fantastic coiling so soon after the nautiloid coil was achieved. Extinction was the reward of its efforts: but the Ammonites knew nothing of that.

Hence, three hundred million years after Lituites' disaster, we find them following his unfortunate habits and developing others even more strange. Though in infancy they held to the coiled shell of their ancestors, they ran riot through youth to old age. Some developed loosely winding shells that dragged clumsily behind as they crawled on the bottom and were useless in attempts to swim. Others looked a good deal

like Lituites; if their shells really were filled with gas (and there's no reason to think they were otherwise) the animals must have drifted or swum head downward. A few began to develop straight cones much like those of Orthoceras—and suddenly changed the plan, to recurve more abruptly than any hairpin. Once the difficult turn was made, the result may have been a great convenience, since it got a long and delicate shell into half of its proper space.

Even stranger, in view of normal Ammonite habits, were the shells that coiled like huge snails. Their owners must have crawled on the sea floor, using their long tentacles as substitutes for feet. It was an unsatisfactory method of progress—yet one far beyond the abilities of those intertwined, wormlike shells that have been found in certain Japanese deposits. For their makers, any movement at all must have been slow and blundering. Their lives probably were spent in quiet repose which rivaled that of their neighbors, the oysters.

The forms of these bizarre shells (Fig. 10F), show how their makers must have lived, and if abundance means anything, some of them were quite successful. Yet if we conclude that they departed from the ways of their ancestors in a successful effort to keep on living, we at once confront this difficulty: Ammonites became extinct in that very age during which aberrant coils became abundant. Like the spiny trilobites, the builders of these knobbed, ridged and twisted shells lived a while and then vanished; nor did simpler kin

manage to survive them. Those "simpler" relatives, with their elaborate septa and shell ridges, so much

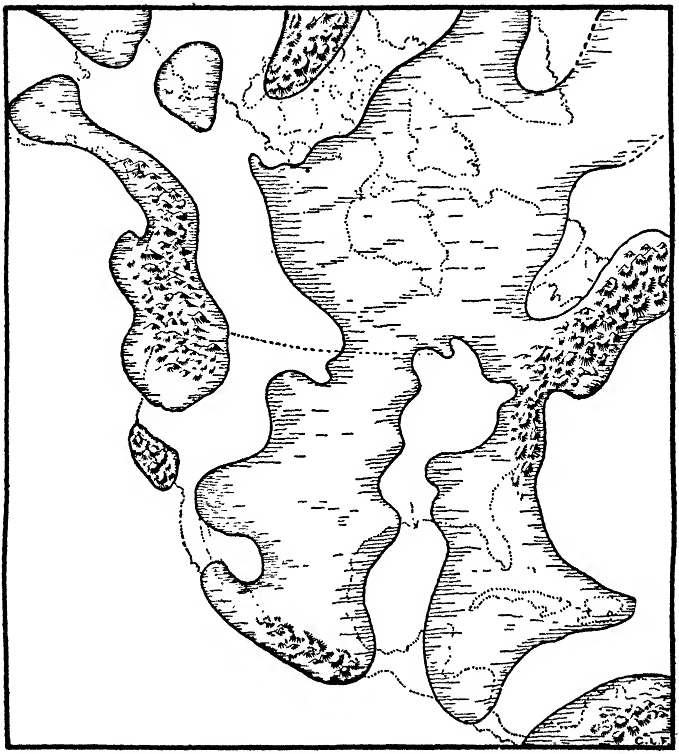

FIG. 11.—NORTH AMERICA DURING MIDDLE DEVONIAN TIME. (SCHUCHERT)

more complex than those of Orthoceras, already had become extinct.

But what, meanwhile, of the simple Horn Shell?

Had he too sunk into oblivion, the victim of weakness or of changed circumstances?

Far from it. Though shorn of its great size and abundance, his race survived into the Age of Reptiles, seeing the Ammonites begin their imposing career. Producing smaller shells instead of larger, they achieved greater and greater freedom; when those shells became so small that they could be enfolded in flesh, a new and important group was born. Called Belemnites, from the Greek word that means a dart, they looked much like the squids of to-day, with cigar-shaped bodies and long tentacles. They swam by millions in the seas of the Chalk Age, in whose rocks their shells are common fossils. As they declined, they gave way to their descendants, the cuttlefishes and squids, some of which are the largest of all known molluscs, as others are the most abundant.

In this contrast between the long-lived Orthoceras with its many descendants, and the spectacular but short-ranged Ammonites, we see the gulf which separates generalized from specialized organisms. The former, while simple and far from perfect, are able to meet varied needs of life, or adjust themselves to new conditions. From their apparently crude bodies, new things may be developed—new kinds of animals and plants. But the latter lack these abilities. Minutely fitted to one kind of life, they are helpless before any other—while from their highly developed forms, nothing really new may arise. About all they can do is to elaborate upon what they have, or lose

something their ancestors developed. Even that does not save them, though for an epoch or age it may delay disaster. Inevitably the balance turns, with extinction the one remaining goal.

CHAPTER V

FISHES IN ARMOR

WHILE crinoids waved to and fro in the water and trilobites crawled about gobbling rubbish, something new appeared in the sea.

It had a backbone of gristle and two flabby fins. So we call it a fish, even though it was quite unlike any fish that lives to-day. Perhaps we honor its good intentions, for in the course of time this simple swimmer did give rise to Simon-pure fishes, as well as to others whose membership in the class is of poorer standing.

Yet these poor relatives deserve attention. They were the first backboned animals to leave remains that are common as fossils, and they were our first inventors of bony armor. Like the knights of *Ivanhoe,* some of them protected themselves so well that they could scarcely move, and so could do little but wait for foes to attack them. That may be one of the reasons why these fishes, like knights, long since have vanished.

One of the best known—and longest lived—of the early armored fishes is Cephalaspis, the Spiny Head. Its body was covered with plated rings of bone; its head, by a helmet shaped like a half-moon. It moved

by wriggling its plated tail, and by two broad flaps near the points of its helmet. Like the clumsier trilobites, it could not rise above the bottom, and its food consisted of dead animals.

Cephalaspis appeared about the time that coral reefs grew on the site of Chicago, and for millions of years he stayed in the sea. But toward the end of the following period that sea sent long bays into Wales and Scotland, and into those bays fresh waters poured. Yet Cephalaspis and his relatives did not leave, and their remains were buried by the thousands in the sands of the bays. There they lay while the sands hardened into sandstone and then arose to become Scotland.

The sandstone was hard, but it also was tough—made so by the decaying flesh of countless fishes. When Scotchmen came to want stone for pavements and sidewalks, they chose this tough, resistant rock. Quarries were opened here and there, and as the workmen hammered and pried at heavy flagstones, they found the remains of Cephalaspis. Stonecutters became fossil hunters, and soon there were great collections of these primitive fishes, gathered from the beds of the Old Red Sandstone.

One of the fossils found most often was that of a fish less than six inches long, so well armored that the quarrymen thought it a turtle or crab. Thick plates of bone covered its head and body, and even the armlike projections from its head by means of which it crawled. Those projections looked a little like the wings of a fledgling bird, so their owner was called

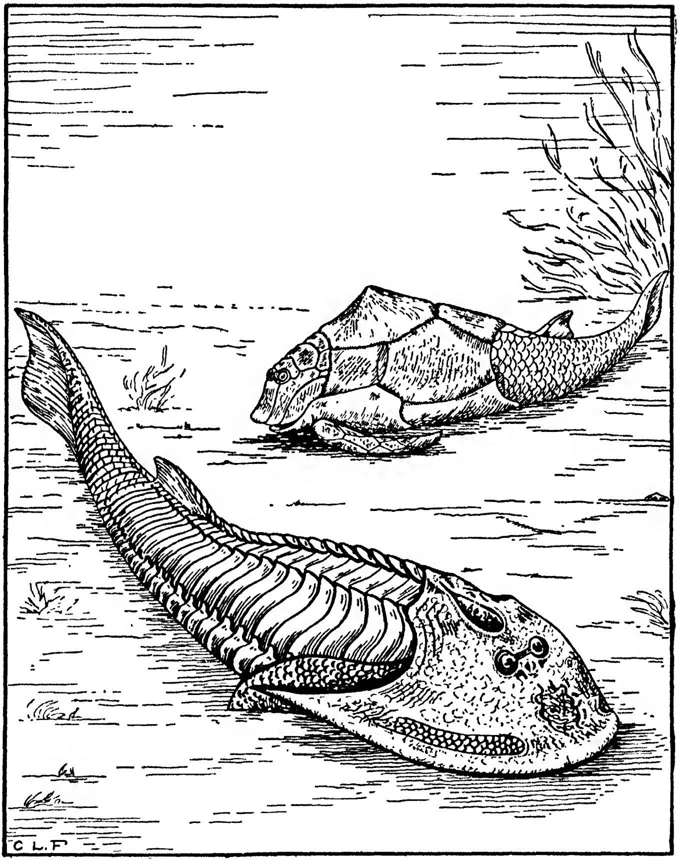

FIG. 12.—ARMORED FISHES OF THE OLD RED SANDSTONE: *Cephalaspis* IN FRONT, *Pterichthys* BEHIND.

Pterichthys, the Wing Fish—a strange name for a creature that couldn't even swim, much less fly.

Although nothing seems to have eaten wing fishes, they were not allowed to die in peace. Great schools of them seem to have become stranded upon sandy flats, and there abandoned by the water. Exposed to the burning rays of the sun, each Pterichthys twisted and struggled till death came by suffocation. Rock layers recording such disasters are strewn thick "with remains which exhibit unequivocally the marks of violent death. The figures are contorted, contracted, curved; the tail in many instances is bent round to the head; the fins are spread to the full as in fishes that die in convulsions. . . . The remains, too, appear to have suffered nothing from the after attacks of predaceous fishes; none such seem to have survived. The record is one of destruction at once widely spread so far as it extended."

These are the words of Hugh Miller, himself a worker in the sandstone quarries, and the man for whom the finest species of Pterichthys is named. Miller supposed that these disasters were caused by eruptions from near-by volcanoes, but the theory of drying sand flats now seems more probable.

Relatives of the wing fish are scattered widely throughout the world, though in a few places they are specially abundant. One of these is a bay on the southern coast of Quebec, where dwelt a rather large fellow called Bothriolepis. Like his Scotch cousin, this

fish often was carried shoreward by the waves and then stranded when the waters subsided. Great slabs have been found, bearing the "shells" of these unfortunates, lying just as they settled into the mud.

The fishermen who dwell on the shores of this bay are almost as interesting as the fossils in them. Living upon tiny hillside farms, these men earn their livings by catching herring. But when there are no herring to catch, and the fields of potatoes need not be hoed, the fishermen take crowbars, chisels and hammers and go down to the shore. There they pry out and open nodules, some of which contain fossil fishes, which are offered for sale to museums and colleges. Thus it happens that in a poor herring year the market is glutted with Bothriolepis.

Neither the armored fishes of Canada nor those of Scotland are very large. But in what is now northern Ohio there lived others—perhaps true fishes—which were the biggest, fiercest inhabitants of their shallow seas.

It's a little difficult to picture these giants, because only their heads and "shoulders" were covered with bone, while their inner skeletons were made of cartilage. Since neither the cartilage nor skin were fossilized, we have to guess the size of the creatures from that of their heads. Since some of these had mouths four feet wide, total lengths of ten to eighteen feet seem quite reasonable, or even necessary.

Although some of these fishes may have swum

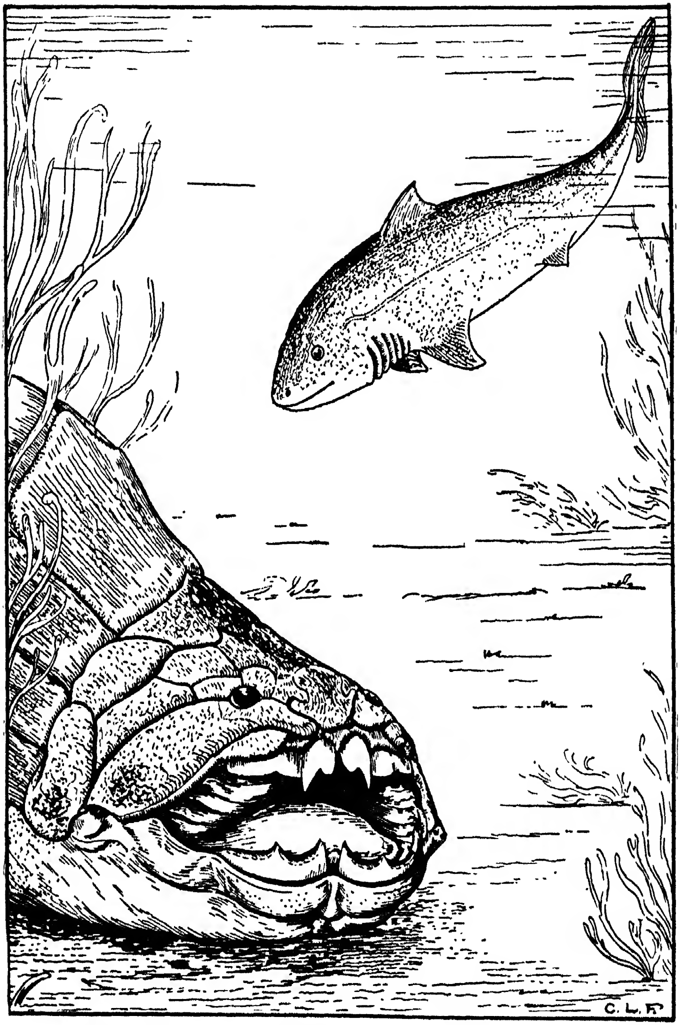

FIG. 13.—SHARK-LIKE FISHES OF THE CLEVELAND SHALE, *Dinichthys* LYING IN WAIT ON THE BOTTOM.

swiftly, their large, flattened skulls seem to indicate that they spent most of their time lying on the bottom, waiting for prey to come near their noses. Then the powerful jaws would suddenly close, the bladelike teeth cutting through the body of even a shark, or tearing deeply into the unprotected sides of other fishes of the same armored kind. For if these monsters were as savage as appearances indicate, they would not have objected to playing cannibal.

CHAPTER VI

LIFE TAKES TO THE LAND

WE have met animals, and a few plants, whose histories stretch through four hundred millions of years. Every one of them lived in the water, and the great majority dwelt in the sea.

This does not mean that we began our survey with aquatic forms and haven't had time to get to the others. Were that the case, we should now merely turn back to the Cambrian period, and there begin our story of organisms that lived on land. For lands undoubtedly existed, forming the shores of the shallow seas, and furnishing the sands and muds which streams carried into them. Yet upon their surfaces nothing lived—nothing, at least, of which we have knowledge.

When their primeval barrens were invaded is a secret not apt to be discovered. The pioneers doubtless were tiny, soft plants that found, in crevices and pools, surroundings that were favorable. But the moment they tried to conquer dry surfaces, they found a series of difficult problems.

The great advantages of water are these: It provides a fairly constant set of surroundings, in which are dissolved those minerals and gases that living things need in order to grow, and to repair the wear and tear

of existence. Food need not even be pursued: sooner or later it will drift into range—or into the mouths of those that need it. Water, another essential, surrounds them, supporting their bodies and preventing all need for its storage.

On land, conditions were very different. Even in damp crevices, the supply of water was limited, while in pools there was constant threat of drying. The successful land-dweller-to-be had to make some effort toward self-support, to secure and save water, and to keep its body from settling down into a formless mass of flesh or jelly.

The first steps toward this goal were taken in the water. Long before trilobites became common, there were plants much like the brown seaweeds of our coasts, with fronds so firm that they became fossilized. Some of them may have found their way to land by exposure when the tide was low; others, by extending their homes into rivers, and from them onto the muddy banks. Animals, too, assumed definite forms, with organs that enabled them to fight or flee and to take advantage of their neighbors. Some, such as the sea scorpions and fishes, often inhabited shallow water or pushed their way up coastal rivers. Several adventurous fishes even took small streams and ponds as their chosen environment.

These were the pioneers destined to lead the class of vertebrates along the path that we call progress. While life was tied even to fresh water, activity on land was out of the question. Imagine, if you can,

a state in which the human race lived with the fishes, attempting to carry out its complex social activities under several dozen fathoms of water! Even the poets of Greece and Rome, who saw no objection to their plan of bringing man into existence beneath the waves, had to get him on land ere he started to function. And though they may not have known it, horses and antelopes, peacocks and lizards awaited the same opportunity.

Thus, the first step in the development of animals higher than fishes was the one by which fishes themselves became able to breathe oxygen from air instead of from water. Like trilobites, snails and Ammonites, the typical fish breathes by means of gills, through whose delicate surfaces oxygen is able to enter its blood. But it can do so only if the surface is moist, and moisture does not last long in air. So long as gills were the best means of breathing, no fish could venture far from water except at peril of suffocation. Since a dead fish is a poor ancestor, we must look to the more prudent (or lucky) ones that managed to change in safety.

They did it surprisingly simply. In addition to their gills, each fish has a bladder that it can fill with air for assistance in floating. Certain fishes of Africa, South America and Australia are able to do this at will; and since the walls of their bladders are filled with blood vessels, oxygen is taken from the air within them. Even when the water is pure, they seem to prefer this simple lung to gills—and when the water

is fouled or vanishes in the dry season, the lung becomes a definite necessity. Without it the fishes would perish, but with it they exist in comparative comfort.

These lungfishes are survivors of an ancient race, whose bones lie in rocks even older than those that hold Pterichthys. Apparently they came into existence not long after the beginning of the Devonian period, often called the Age of Fishes. Yet in spite of their antiquity they were not really primitive, nor were they the ancestors of land-dwelling vertebrates. That honor, or fate, was reserved for a still simpler group of fishes that also could make lungs of their bladders and thus tide themselves over when water was scarce. Though ugly, slow and undoubtedly stupid, they possessed two virtues that the lungfishes lacked.

One of these was a plastic ability to change, such as we found in old Orthoceras. The other was a set of four fins whose bones were not highly specialized. By enlargement of some and the loss or shifting of others, each fin became a stubby leg on the end of which was a foot with toes. Just how many toes is uncertain, since some forms seem to have had six or seven; but by the time that feet grew useful, five had become the standard number.

That time did not come at once. The first legs were of small value for walking, and the first lungs did not always work. Animals equipped with them had to begin life as fish-shaped tadpoles, with plumed gills and strong tail fins. With growth, legs appeared and lungs became stronger, finally replacing gills. The

proud, dull rebels could breathe air, but their flabby legs were used for swimming. Had he not been too stupid to think of it, the first animal who used his legs as a means of crawling over a sandbank should have raised the red flag of revolution. He had done something unheard-of before, and had won new worlds for his unhatched descendants.

Yet they were not in any hurry to seize it. The first known footprint was made by an animal much like a salamander, crawling on a sandy Devonian shore. Perhaps he was looking for a meal in the dead bodies washed up by waves, or in clumsy insects hunting among them. His weak legs could not lift his body; and as they strained and pushed in their effort to move it, one foot dug deeply into the sand. The imprint hardened and was covered, becoming the world's first record of Devonian amphibians.

These relatives of the frog and salamander may have been fairly common—but if they were, fossils fail to show it. In any case, they were largely aquatic. Their jelly-masses of eggs were laid in water; the plume-gilled tadpoles would have died out of it. The few that were strong enough to adventure came back to the home pool for mating, there to return to the shelter of water, and in it deposit their young.

Real conquest of the land demanded further change: eggs that carried their own supply of liquid stored away in protective membranes, and young whose lungs were ready for use when they hatched. Such departures were beyond the power of amphibians whose

bodies remained typical of their kind. When they appeared, they were accompanied by changes in flesh and skeleton that marked a new class of vertebrate. We call them reptiles; and though the first ones looked much like salamanders, they gave rise to the land's first rulers, and the mightiest animals that have lived upon it.

Yet we must not allow our enthusiasm for creatures endowed with backbones to obscure the achievements of other organisms. Reptiles used their strengthening legs to crawl through forests whose ancestors had shaded the first amphibians. Beneath them grew tangles of moss and seed ferns, while vines clung to their trunks and branches. On the shores of ponds and in broad swamps grew thickets of horsetail reeds: not the short, slender things of to-day, but thick stalks thirty feet in height. Here and there, masses of dead leaves, trunks and stems were gathered by streams, to be carried into quiet pools where they settled into thick beds of black muck, the first stage in the formation of coal.

Nor were these deep forests of the Carboniferous period given over only to reptiles. Among the roots and ferns crawled cockroaches four or five inches long, with antennæ that pried into hidden corners and warned of dangers that could not be seen. Clumsy, winged species crawled about on branches or flew slowly from one to another in search of fat and defenseless larvæ like those which still remind us that

the ancestors of insects were wormlike nephews of trilobites. In open spaces dragonflies rested or swooped about on colored wings whose spread was twenty to thirty inches. With their own methods of eating and breathing, and with skeletons about them instead of within, these early insects had met and solved the problems that still troubled land vertebrates. For millions of years, they were far ahead in the race for existence—and they have not lagged far, even unto to-day.

CHAPTER VII

DEATH ON A DELTA

WHILE the Coal Age forests were spreading, and reptiles learned to walk on their legs, even greater changes were taking place. All over the earth, regions that had lain under water became land, while parts of the land were shoved up into mountains. Out of sediments that had gathered in long, shallow seas, the Appalachian ranges were born, some of their peaks rivaling the present Rockies. Tributary chains reached westward to Oklahoma; to the north stretched a broad upland, while a retreating sea lay to the south. Into it drained rivers from the highlands, bringing loads of silt and sand that slowly grew into a broad, low delta that to-day is part of northern Texas.

Among its swamps and sand hills, in the Permian period, lived an astonishing array of amphibians and reptiles, whose bones were buried in the gathering strata. Of course, many of the dead bodies that found their way into the Permian rivers already had been torn to pieces, or had decayed until currents could tear them apart. Hence, when they finally sank to their burial, they were little more than fragments: water-worn leg bones, single vertebræ, or broken jaws and bits of skull, on which only shreds of flesh remained. In some places these water-worn fragments,

now replaced by stone, are so abundant that they may be shoveled up by truck loads. Yet the seeker after

FIG. 14.—NORTH AMERICA DURING THE EARLY PERMIAN PERIOD. (SCHUCHERT)

fossils passes most of them by, for in their scattered and broken condition they are worse than useless for study.

Yet not all the fossils are so very imperfect. Now and then a dead animal fell into the water unmangled; distended by the gases of decay, it drifted downstream until it either sank to the bottom or stranded beyond the reach of scavengers. Buried in the gathering sand or mud, its bones were preserved with remarkable perfection, and in the positions they held during life. Such perfect skeletons are rare, but they record in detail both the forms and the habits of the beasts that lived on that Texas delta.

The lowliest of these were amphibians, cousins of the frog and salamander. Yet they had changed vastly since their first known ancestor left his one footprint on a Devonian shore. Instead of "bones" that were little more than cartilage, they had skeletons whose ponderous strength exceeded any possible need. Skull and limb bones both were massive, while vertebræ sometimes were fused, or crowned with massive, immovable shields.

The giant among these heavy amphibians was a short-legged beast called Eryops, whose total length was about eight feet. He looked something like both a frog and salamander; and though his leg bones were so very massive, they scarcely could lift him above the ground. His skull was a marvel of heavy armor, deeply pitted and rough—even though it looked like that of a frog. His jaws were set with sharp, cone-shaped teeth and a few specially powerful tusks. The position of Eryops in Permian Texas was that of the crocodile in the Nile. Probably he spent most of his

time lying on warm, steaming sand bars, or waiting with only nostrils and eyes above the water until the approach of a victim aroused him to action. Even that amounted to little more than one clumsy rush and snap, followed by tearing and swallowing of food and another long wait in water or on sand bar.

Some of Eryops' neighbors were more active, wandering here and there over the land. Cacops, for

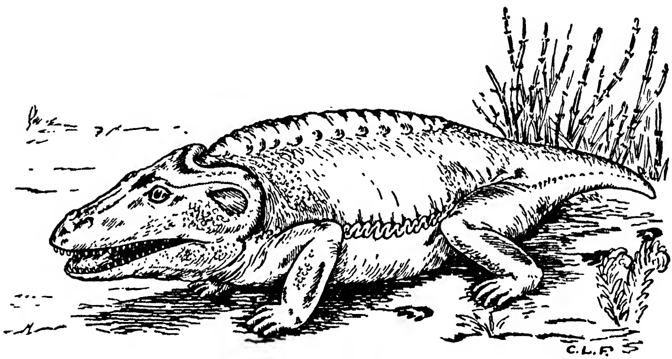

FIG. 15.—THE AMPHIBIAN, *Cacops,* ON HIS WAY TO A STREAM.

instance, was a persistent traveler, his stiff body with its back-crest of bone waddling slowly along upon stubby limbs. Often he and other species chose well-marked paths that doubtless led from one pool to another, across damp stretches of sand. In the walls of the Grand Canyon such paths have been discovered—yet they merely offer another puzzle. Of the uncounted hundreds of footprints in them, all point in

the same direction. Travelers went but did not return: where, in the end, did they go?

Eryops' broad mouth may be part of the answer; yet the prey that entered it was not always Cacops. A more likely victim was the water dweller called Diplocaulus, the strangest of all strange amphibians. The member of a race whose outstanding achievement was the production of legs and lungs, Diplocaulus was unable to walk or to wander a yard from the edge of water. His body was long, almost eel-like, his ribs were weak and his legs small and feeble. Yet this slender frame supported a head that was broad and massive, with long points of bone to the sides and rear. Eyes and nostrils were directed upward, while the small mouth lay beneath. Probably the animals spent their entire lives half wriggling, half swimming along the bottom, finding food on the sand or mud. Rare gulps of air must have satisfied them—or perhaps, like some mud puppies, they avoided even that necessity by retaining gills throughout their lives. It is thus that the picture on page 62 shows them, their bodies resting in a tangled huddle at the bottom of a Permian pool.

Yet amphibians were not the chief denizens of the delta, either in abundance or variety. Descendants of the reptiles that had crawled so slowly through the Carboniferous forests were the real rulers of the scene. Small and large, clumsy and swift, plain and ornate, they ranged through swamps, groves and sandhills,

crowding the less able amphibians to the verge of extinction.

Yet the simplest of the reptiles were not a great improvement over their forebears. The one best known had a thick body some two feet long, part of which was a dragging tail. Its legs were short, with

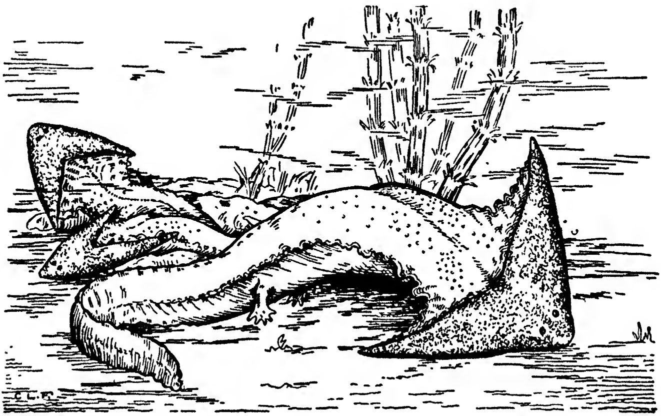

FIG. 16.—*Diplocaulus* AT REST ON THE BOTTOM OF A POOL. (GREGORY)

weak muscles; its jaws were set with cone-shaped teeth that overlapped instead of meeting. Such poor dentition indicates a habit of feeding on defenseless young vertebrates or insects, which were swallowed whole without attempt at chewing. Though reptilian foods have changed through the ages, this manner of eating has persisted. Prey may be torn to pieces, or crushed to a size that can be swallowed, but the whole task of digestion is left to the stomach and

intestines. Jaws and teeth do not participate—nor do they in reptiles' offspring, the birds.

In the forests that sheltered the most primitive of known reptiles (named Seymouria from its home, Seymour County, Texas) there were species with the habits of lizards, and others that crawled or lay in

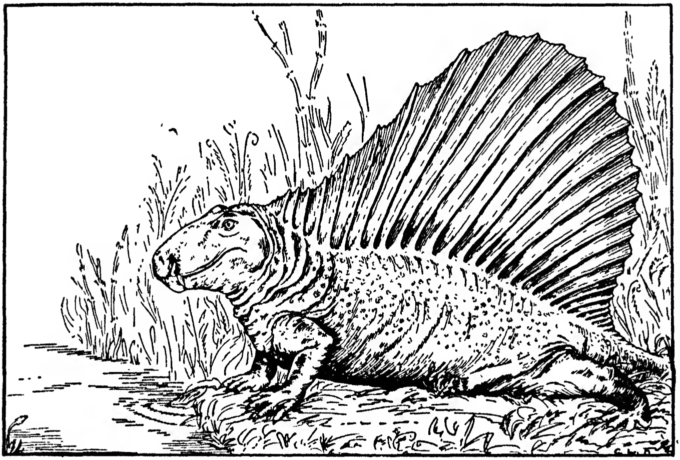

FIG. 17.—*Dimetrodon,* "TIGER OF THE PERMIAN DELTA." (GILMORE)

wait for prey. The largest of these were savage carnivores, the tigers of their early, slowly moving world. Some of them indulged in types of ornament that would have made even a tiger's stripes look tame.

The climax among these large flesh eaters was reached by an animal called Dimetrodon. The name refers to its two sorts of teeth: long, pointed tusks

in front, and shorter, sharp-edged ones behind. The former extended three or more inches beyond the heavy jaws; while the latter, recurved and serrate, offered tremendous cutting power. A more effective set of jaw-borne weapons for seizing, slashing and holding prey is not to be found in the reptile kingdom, even though some of the carnivorous dinosaurs did achieve teeth of much greater size.

The full-grown Dimetrodon was eight or nine feet from nose to tail tip. His head was long, high and narrow, his legs short but strong, their feet armed with claws. But the most striking of his features was a broad, finlike expanse of skin borne on slender spines above his back. These spines, extensions of the vertebræ, tapered almost to the delicacy of a whip lash and often were broken. More than one fossil shows them bent and healed—and the fact that most of these injuries are near the tail indicates that they were made by enemies.

Knowing his form, surroundings and neighbors, we may picture Dimetrodon's habits with ease. Though savage, he was not an active prowler, tracking the game on which he fed. Rather, he crouched in the concealment of reeds and seed-ferns, at the bank of a pool or stream. There he remained until the approach of Eryops or Seymouria provoked a fierce, swift rush and slashing of teeth. If the victim escaped, Dimetrodon resumed his waiting; if not, he settled down to the work of devouring his prey, his wide mouth

engulfing great chunks of meat shorn off by his serrate teeth.

Yet his conquest was not always without challenge. If two reptiles watched the same pool, the maker of a kill was sure to be faced by his less fortunate rival, hungry and ready to fight for food. Scars and broken bones record furious contests over fallen amphibians, or for vantage spots beside some stream or trail. If opponents were evenly matched, one might settle the matter by fleeing; but when one was much weaker than the other, the result more often was a cannibal meal.

Though Dimetrodon was the most savage reptile of the Texas delta, he was far from being the most bizarre. That honor, not rare among fossils, belongs to another of about his own size, whose fin-bearing spines were equipped with crossbars. But in spite of his fierce appearance, the animal was a peaceful eater of clams, snails and plants. His incisor, or biting teeth were chisel-like, as though used in cutting strong, coarse plants. Behind them were five triangular teeth somewhat like those of the lion and tiger, followed by simple cones much like those of the primitive Seymouria. To complete the series, both the roof and floor of the mouth were set with short, flat teeth like those of animals that feed on shellfish. This reptile could bite, shear, gulp or crush, with a special set of teeth for each function and diet. Thus omnivorous habits were assured—at a striking loss of simplicity.

Though varied teeth prevented starvation, they did not protect their owner from enemies. A large body that could move but slowly, jaws without weapons and skin without armor—all invited the attacks of Dimetrodon and carnivores of even smaller strength and size. It is a rare skeleton indeed in which broken, healed bones do not record injury in spite of escape, while the multitude of scattered remains testify to encounters that ended fatally.

For there was small room in that Permian delta for animals that could neither flee nor attack—that forsook the safety of water without the protection of armor. Despite weak legs and poor brains, life was a matter of escape and aggression; while limitations that were shared by all reduced all to an equal plane. Slow prey fell before slow pursuers; increasing weight of bone added as well as removed problems. Advantage still lay with freedom and speed—but rulers of the Permian swamps became increasingly ornate and clumsy. Yet as the continents continued to rise, they called for new and more active animals. Dimetrodon vanished with his favored delta, while smaller, less ornate forms survived.

CHAPTER VIII

AGES OF GOBLINS

AS rivers built the delta of Texas, the earth passed through a revolution. Sea bottoms continued to become land; mountains rose higher and higher; climates of ages were turned topsy-turvy. Once moist lowlands became arid—yet near them, coal forests survived. Northern temperate regions remained moderate; but south of the Equator, glaciers spread across subtropical plains. The homes of reptiles vanished under ice sheets, and those of fishes were given to reptiles.

From such apparent chaos emerged a new era—a time of returning equable climates and of continents invaded by seas. Upon them dwelt none of the Permian monsters, even though they came to be peopled by reptiles whose size and ferocity are without equal. So abundant did their class become that lands failed to hold them. Many of their members returned to the sea.

The length of the Mesozoic era—or as it generally is known, the Age of Reptiles—was about one hundred forty million years. During its early portion, the Triassic period, our attention is centered upon two regions. One is the already familiar Southwest; the

other, a series of valleys that lay between the then towering Appalachians and still older lands to the eastward. The floors of these valleys were often flooded, their sandy muds alternately moist and exposed to the sun. Marks made by ripples and currents, pits impressed by falling raindrops, cracks formed in drying mud—these and a dozen other features record the forces and climates of those ancient flood plains.

Yet our interest soon turns to the footprints that are scattered among these inorganic records. They look like impressions of the feet of birds, and were thus regarded by early Yankee quarrymen. It was found, however, that they were made by reptiles of the sorts that we generally group as dinosaurs. Many of them were as small as a cat or crow; the largest were ten or twelve feet long, their footprints being built in proportion. The only one whose skeleton has been found was a slender species four feet in length, of which the tail made more than half. Like most of his relatives, he walked on his hind legs—which accounts for the birdlike tracks that he left behind in the sandy muds.

Though so common in New England and New Jersey, the Triassic dinosaurs were less abundant in the West. Dwellers of high valleys and uplands, they would have been out of place in the salt marshes and swamps that stretched from Wyoming to Texas. In them dwelt animals ancestral to crocodiles, others which

in habit were like them, and some whose relationships still are something of a mystery.

Those nearest the crocodiles were small creatures, two or three feet in length. They spent most of their time in the water, where they often had to flee from the much larger "false crocodiles" or phytosaurs. Like the living gavial of the Ganges, these reptiles had long, slender jaws studded with teeth, of which the longest were at the very tip. Unlike the gavial, however, their nostrils lay close to the eyes instead of far out at the end of the snout. Their long, flat tails were used in swimming, their legs, for short walks on land. Sometimes these took them from one stream to another; more often, their trails ended on the nearest sunny sand bank, on which dozens of phytosaurs would gather to hiss and grunt at one another until they at last fell asleep. When hungry, they crawled or trotted back to the water, there to lie in wait for prey with only their nostrils above the surface. Since these and their eyes lay side by side, there was little to warn intended victims—and the phytosaur's long, sharp teeth left small chance for escape once prey had been captured.

The scene now shifts to Wyoming in the second or Jurassic period of the Age of Reptiles. Broad swamps stretch before us, their banks clothed in trees that resemble palms. In the distance rise a few low hills, from which flow broad and shallow rivers that wind to and fro in their sandy channels. Though the region is one from which mountains will rise, they are not

foreshadowed by its subtropic marshes and lowlands, which extend from New Mexico to Montana.

Among the succulent plants of the bayous, a great dripping and splashing prevails. Blunt, stupid heads rise upon snaky necks that are borne by partly submerged bodies. There are hints of massive shoulders and legs—of long, muscular, lash-tipped tails.

We are watching a herd of feeding dinosaurs, the most powerful denizens of Mesozoic America. The shortest is more than sixty feet long, and the longest an inch or two less than ninety. Weights range from twenty to thirty tons, yet brains are limited to ounces. Despite their size and imposing titles, these monsters are both dull and peaceful. Their chief concerns are water for wading and plants for food, with enough sunshine to make them comfortable. They care neither for battle nor rivalry, each reptile wandering about indifferent to its neighbors unless they happen to block its way. Without thinking much about it, they know how to walk, eat and avoid danger, and to mate with their kind at the proper season. Beyond these limits their minds rarely go.

In spite of their size and other differences, these great herbivores are descended from the small reptiles that ranged the Triassic valleys of New England and Europe. Though less specialized than those of the birdlike footprints, they walked and ran on their hind legs, using their tails to balance their bodies. Prey was caught in their sharp-toothed jaws, but their forefeet may have been useful in nest robbing. Although

they did not go far from streams, they preferred dry land to water.

From such generalized ancestors two contrasting groups of reptiles arose. One included those we've just seen: huge quadrupeds with massive, elephantine legs, thick bodies and long necks and tails. Their heads always were small, and bore teeth that were both few and simple. Probably they were just sharp enough to cope with the soft marsh plants. Thus food, like habitat, was a matter of necessity, not choice, with these swamp-dwelling dinosaurs, whose teeth were too weak to cut plants of the land and whose legs were useless out of water. Only with the buoyant aid of water could they support the enormous bodies above them, whose weight, as we've said, reached thirty tons.

Indeed, they exceeded it by ten tons in one group that ranged from America to Africa. The upper leg bone of one of these reptiles is more than seven feet in length, and the rest of the skeleton is in keeping with it. The height at the shoulder was twice that of the elephant Jumbo, while the neck arose twenty-six feet higher. Although the tail was shorter than in some species, it was very thick, thus adding its part to the forty tons that the beast must have weighed.

Such dimensions should have satisfied any one—yet the plain fact is that they didn't. Parts of several skeletons were found, and when combined on the plan of more slender relatives they gave dimensions truly amazing. "When stretched out on the shore, resting on the belly," wrote one newspaper scientist, "the body of

the great lizard of Tendagaroo bulked like a breakwater 12 ft. high, and his tail like a huge serpent extended 80 ft. beyond it; whilst his head and neck reached 40 ft. along the mud to the front." In all, about one hundred forty feet of reptile—enough to please any reporter! Unhappily, the bones refuse to bear out his estimate, or to classify their owner as a lizard. He was a typical, wading dinosaur—a mere eighty feet from tip to tail.

The huge stores of food in these defenseless swamp dwellers offered rich opportunities to their flesh-eating cousins. These, as we have seen, began as long-legged hunters whose food was the flesh and eggs of reptiles, and such other creatures as fell in their way. Some of their offspring clung to speed and agility, but many developed large size. The biggest ones failed to rival the herbivores: yet in the forests that fringed the Jurassic swamps there stalked dinosaurs thirty-four feet long, whose great ambition was to kill. Their hind legs were long and powerful; their toes were armed with talons, while their large skulls and jaws bore six-inch teeth, replaced as fast as they were broken.

Before such engines of destruction, the herbivorous types sought the protection of deep water. Yet not always were they successful: a careless wader, coming too near the shore, would find himself seized by rows of merciless teeth, his body torn by powerful, clawed feet. The unequal struggle soon was ended, and the victor dragged his prey to the bank, there to tear it to bits at leisure. Scarred and broken vertebræ, among

which lie the fractured teeth of carnivores, record the outcome of these struggles.

Large though the Jurassic hunters were, they were by no means the greatest of predatory reptiles. Lagging in their development behind the herbivores, these

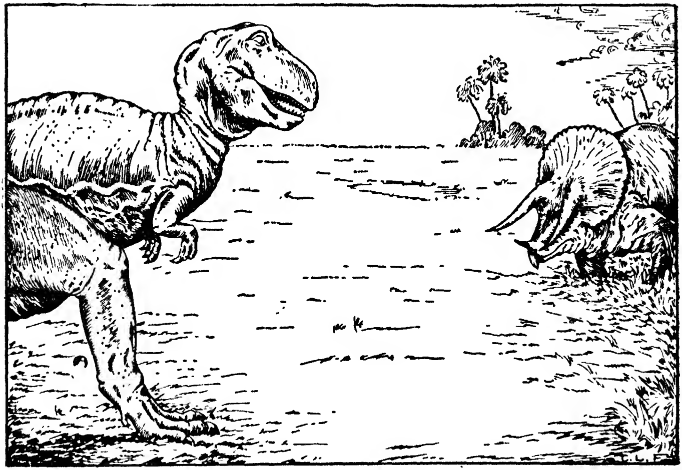

FIG. 18.—*Tyrannosaurus* STALKING THE HORNED TRICERATOPS.

Each represents one order of the so-called dinosaurs. (Knight)

creatures did not reach their zenith until an age from which their biggest and weakest prey had vanished. Tyrannosaurus, the largest carnivore, lived during late Cretaceous times: near the end of the Age of Reptiles and millions of years after the last great "lizard" of Tendagaroo had drifted downstream to a muddy burial.

Yet Tyrannosaurus was forty-seven feet long, with a height of eighteen or twenty, and a weight greater than that of Jumbo. His mouth, almost as long as the four-foot head, had powerful jaws and knifelike teeth, while the talons that armed his broad hind feet were six to eight inches in length. His forelegs, however, were very weak and short—too short even to reach his mouth.

As he ranged the slowly rising plains, Tyrannosaurus was the largest and strongest carnivore ever seen upon land. In case of attack, he was ready for any comer—though few not of his kind dared approach him. But in seeking for prey he was less fortunate, for his prospective victims were not the simple, defenseless creatures that had wallowed and fed in Jurassic swamps. Some were swift runners and swimmers; others were armored forts of flesh upon which the longest of teeth were useless. They had followed the example of Tyrannosaurus himself, and against his teeth and muscles opposed agility and weapons as well as armor, plus a surly temper that made them willing to stand their ground before all opponents, no matter how large or how savage.

CHAPTER IX

DINOSAURS IN BEAK AND ARMOR

WHENEVER destruction threatens, many animals find means to avoid it. In some, these take the form of keen mind or ready instinct, coupled with agility of body. In others, there are special structures whose sole value seems to lie in the prevention or repair of injury. Why they were developed, we do not know —nor do we know why they so often are matched by other species whose ways and structures seem perfectly fitted to overcome these means of protection.

Yet doubt as to causes does not weaken the fact. The most cautious skeptic in evolution admits that since the very beginning of animal history, attack and defense have gone together. The hard tests, or shells, of Cambrian trilobites turned the strong pincers of some of their neighbors, while blind dwarf species found safety in burrows. The shells of cephalopods protected their soft bodies, while their long tentacles were weapons of attack. All record the ancient struggle among things living; of the need to kill and the threat of destruction that are two keynotes of nature.

One of the commonest means of attaining safety, and one readily shown by fossils, is the development of some form of armor. Many an ancient invertebrate

was more heavily plated and bossed than any knight who fought under Joan or Maximilian. Trilobites, clams, lampshells, Ammonites—these and many others set examples in protection that vertebrates were not loath to follow. Pterichthys was a marvel of bony helmet, cuirass and mail. In its relatives of Quebec, armor did not extend to the tail, though the head and trunk were thickly covered. Armor was lacking in the first amphibians, since their "bones" consisted of little but cartilage, but in their Permian descendants it appeared once more in the form of ponderous skulls. Yet the soft, defenseless condition of their bodies casts doubt on the value of such protection. Of what use was the thick skull of Diplocaulus, which was attached to a remarkably feeble frame? May its owner not have been in the position of those medieval knights who, unhorsed and fallen, found themselves unable to fight or flee?

Yet armor is armor, even if worthless, and animals continued to make it. Though the first reptiles were smooth of skin, the ancestor of crocodiles was plated, while even the savage phytosaurs wore scales. One of their neighbors was a crawling collection of plates, points and horns; and some others were not far behind him.

Few early dinosaurs indulged in armor. Small ones sought safety in running; larger kinds pursued them by speed. The huge herbivores found comparative safety in the water, where their chief enemies could not follow. When plates and spines at last were adopted, they appeared in reptiles so unlike the more familiar

dinosaurs that they keep the name only through convenience. Their differences show in both teeth and armor, but are even more clear in the bones of the hips. Those of Tyrannosaurus and the gigantic waders are like the hip bones of most other reptiles, while in members of the second group they resemble the hips of birds. Thus the creatures called dinosaurs belong to two groups, each independent of the other, and each achieving enormous size.

Like the others, these bird-hipped dinosaurs or Ornithischia made their appearance in the Triassic and soon gave rise to two main groups. One of these led to tall, timid herbivores whose chief food was plants and molluscs. Some ranged in herds through Jurassic Europe, where they furnished food for early carnivores. Later ones dwelt in New Jersey, and in swamps and lakes east of the Rockies, where they swam slowly through deep waters or waded and fed near shore. It was they who merit the name "duckbills" since their jaws were encased in broad flattened beaks, well suited to grubbing in mud. Several also indulged in bony crests on their skulls, some of which reached backward to their shoulders. Doubtless they often fled before relatives of Tyrannosaurus, or perished beneath their claws and teeth.

Yet some of their kin had no need to flee, even before the mightiest carnivore. The best known, perhaps, is Stegosaurus, a twenty-foot walking fortress that roamed the forests of the late Jurassic. His head was small and his brain was simple—but his sides and

flanks were studded with bone, two rows of sharp plates ran down his back, and his tail was set with two rows of spines. He could confront an enemy with something more persuasive than armor: one blow of that spiked and muscular tail would teach caution to the hungriest carnivore, while a pounce delivered on his sharp back-plates would net little but pain and broken teeth. When Stegosaurus became extinct (as he did at the end of the Jurassic period), he succumbed to attacks more persistent and subtle than those of any carnivorous reptile.

For a time, armor seemed out of fashion. Then, toward the middle of the Cretaceous period, there appeared a new group of herbivorous dinosaurs that in their own way outdid even Stegosaurus. By limiting shields and weapons to their heads, they retained their ability for active movement. Thus they held their own to the end of their era, keeping even Tyrannosaurus at bay.

The earliest of these armed, shield-bearing dinosaurs was the famous one called Protoceratops, whose name means "The one before the horn-heads." It was he whose nests, eggs and offspring were discovered in the desert of Mongolia, in rocks that once were drifting red sands. In these sands, Mother Protoceratops scraped a shallow hole in which her eggs might be sheltered. Perhaps she threw sand upon them and went back to her browsing; more probably, she kept near to warn away nest-robbing species. Yet the sand often defeated her efforts, burying eggs before they could hatch,

or overwhelming flocks of infant dinosaurs as they slowly crawled behind their parent. Fossils range from broken, abandoned shells to others which cover the bones of embryos—and from the skeletons of infant dinosaurs to those of their fully grown relatives. In fact, we know more about the development and ways of this early Ceratopsian than we know about any of its successors.

Though Protoceratops had the bony shield of the head, and jaws encased in beaks, he lacked the horns which armed most of his descendants, yet by the time the latter reached North America, they bore horns above both nose and eyes, and spikes on the rims of their broad head-shields. When those spikes were long and directed backward, they must have prevented attack from the rear, while the shields themselves met blows from the side, or thrusts delivered on the neck and head.

Most elaborate of these spined reptiles was one whose serrate shield bore tips of horn, while two sharply curved points bent forward and downward. In front of them lay slopes of thick bone, while the massive eye sockets bore horns and another projected from the nose. The jaws also bore horny beaks, most often used for clipping herbage, yet important weapons in close combat. Whether the skin of the body was plated or smooth is a question not yet determined—perhaps plates were an unnecessary addition. So long as the reptile kept his bristling head turned toward an enemy, he was safe from any normal attack.

Though the most ornate, this creature was by no means the largest of the horned dinosaurs. The record in heads goes to Torosaurus, whose skull and shield measure eight feet seven inches, with horns above the eyes nearly three feet long. The most ponderous body belonged to Triceratops, who was built a little like a rhinoceros, and reached a length of twenty feet. More than a third of this consisted of skull, which, with its horns and shields, often exceeded eight feet. The spikes which it bore above the eyes were longer than the one upon the nose, while the pointed beak made an excellent weapon in fights that came to close combat.

The form and bulk of the full-grown Triceratops leaves little doubt of the creatures' habits. Short of limb as well as neck, they rarely ventured into water. Probably they gathered in small bands or herds of one big male and three or four females, ranging the more open valleys to browse the plants of their thinning forests. The females laid eggs and guarded their young, which ran with the herds for several seasons. The bulls watched their small bands jealously—and at least part of the time nursed bad dispositions. The approach of a rival was signal for combat, which consisted of thunderous rushes, ending in blows against horn and head shield. More than one fossil bears scars of such struggles waged for mates, for food, or for the joy of struggling.

While the horned dinosaurs thus rose to power in the uplands, a group of their relatives became marvels of armor and stupid safety in the swamps that lay not

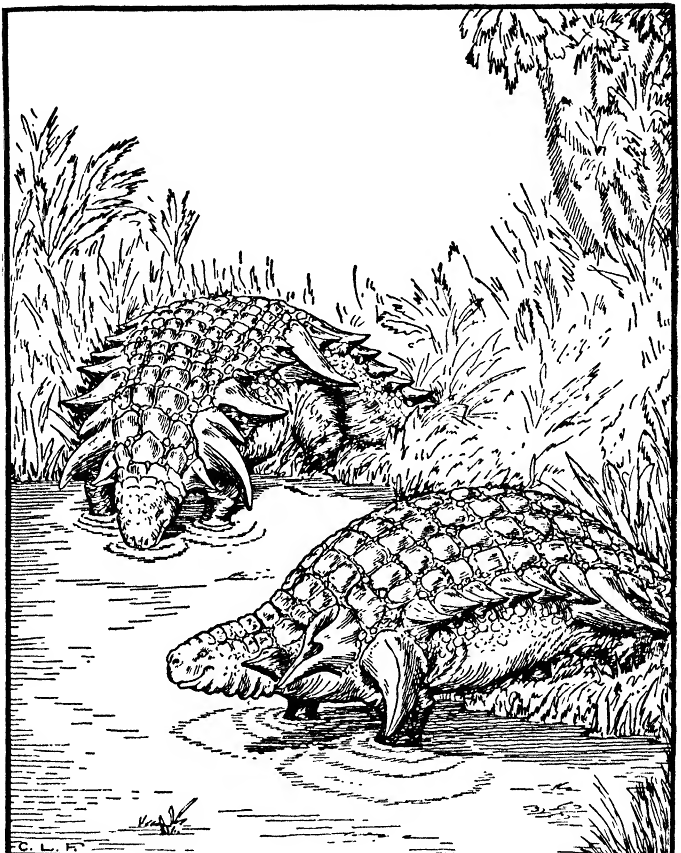

FIG. 19.—THE DREADNAUGHT DINOSAUR, *Paleoscincus*. (MATTHEW)

far distant. Neighbors of the beaked and crested duckbills, they found other ways to food and safety—and in doing so, sacrificed freedom.

Most familiar of these massively plated reptiles is one called Ankylosaurus. About as large as the Jurassic Stegosaur, it was very different in shape. Where the latter's body was high and narrow, bearing tubercles and plates of bone, that of Ankylosaurus was broad and low, and shielded from head to tail by massive interlocking plates. Its spreading ribs were fused to its vertebræ, making a solid support for the covering of armor, and a body that no opponent could crush. On his broad, blunt skull the plates were united with the bones beneath, while nostrils and eyes were shielded by armor. Short, massive legs dragged this queer monster clumsily over reedy mud flats, his thick tail dragging behind. This muscular organ, tipped with a giant's club of bone, was the Ankylosaur's weapon on those rare occasions when he had to fight. His normal method of settling an argument was to squat closely against the ground, his legs tucked close to his body. From that position nothing could move him unless it were an earthquake—and against earthquakes nothing can be safe.

What seems to be the limit in spiny armor was reached by another beaked, bird-hipped dinosaur that dwelt in the swamps with Ankylosaurus. Like many another fossil animal, it was known first from scattered teeth. Since the beak had allowed these to degenerate till they resembled those of a lizard, the beast

became Paleoscincus—the ancient skink. A few bones would have prevented that blunder: for while the skink is a small and unprotected lizard, his ancient namesake weighed several tons and was coated with armor. A name meaning "dreadnaught dinosaur" would have been more appropriate. No animal ever lived more deserving of such a title than this ancient reptile of Montana and Alberta.

His body was broad and flat, his head was small and his legs were stocky. Along his back ran series of plates which extended forward onto his head. From neck to tail, his sides were set with massive spines, the largest of which were at the shoulder. Sticking out from either side, they must have made the Dreadnaught Dinosaur look a good deal like one of the sword-studded chariots in which ancient Persians galloped to conquest—though the reptile was too clumsy to gallop. The best he could do was to creep slowly from glade to pool, or to stand quietly while feeding. His defense, like that of Ankylosaurus, was to stretch full length upon the ground, his plates protecting his upper surface, while spines guarded his legs and sides.

Thus he existed in sluggish peace, while the Age of Reptiles approached its end. He spent much time on sunny mud banks, for his mind was as sluggish as his body. Probably he was not enough interested in life to struggle for mates as did Triceratops—while the lady of his dreams was much too indolent to excite him to pursuit and capture. When hungry, the pair lifted their heads and bit off the plants that grew about them;

when thirsty, they found water at their sides. Unlike birds and some mammals, they did not migrate, for one

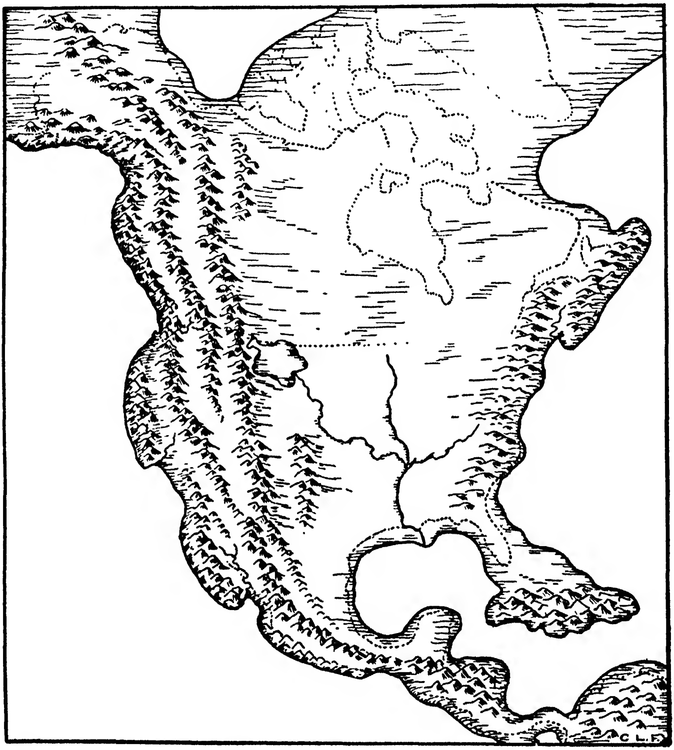

Fig. 20.—North America in the late Cretaceous, near the close of the Age of Reptiles. (Schuchert)

place seemed as good as another, while climates were almost uniform. The haunts of Triceratops did not

tempt them; distant seas held no enchantment. In the still lush lowlands they idled and mated, watched their young hatch and fall prey to carnivores, or grow into dreadnaughts like themselves. Theirs was life at its lowest limits—a simplicity that held no promise, and failed ere a new age began.

CHAPTER X

SAURIAN SWIMMERS

WHILE dinosaurs ranged the swamps of Wyoming, salt waters swept over much of Europe. In the one-time muds of the sea floor, lie the remains of shells and other bottom dwellers, and reptilian bones which at first sight seem to be those of fishes. They were thus described almost two hundred and fifty years ago by a Welsh naturalist named Lluyd, who thought they had grown in the solid strata from eggs driven downward by rain. Strange though his hypothesis was, Lluyd did better than the German professor who described similar bones as the vertebræ of human beings drowned by the flood that floated the Ark.

Nor was the Welshman's other mistake surprising, for the bones were those of no typical reptile. Their owners had the forms and habits of fishes, and like them, were helpless on land. So much did they look like long-nosed sharks that the very man who learned their true nature named them Ichthyosaurs or "fish lizards."

These marine reptiles, whose lengths ranged from two to thirty feet, had bodies like those of sharks or dolphins and snouts which suggest those of swordfishes. Their nostrils lay close to their enormous, goggle eyes,

each of which had a strengthening ring of bony plates. Their necks were short and almost motionless, but their long bodies were lithe and agile. Tails were long and muscular, with sharklike fins of flesh and skin. Instead of legs, the Ichthyosaur had paddles, excellently fitted for swimming, but of no value for crawling or walking. No fish lizard willingly ventured on the shore, while if washed there by the waves of storms, he floundered helplessly upon it. Doubtless some of the many Ichthyosaur fossils represent animals thus cast on the beach, where they died while struggling to reach the water.

Though they swam by thousands in shallow seas, the fish lizards preferred open water. There they darted in pursuit of fish or followed schools of squids, which they caught in their short, curved teeth. Many skeletons have been found which are surrounded by black films of carbon that show skin, muscles and fins, while masses lying in the region of the stomach contain the remains of undigested meals. Near them may lie the bones of young Ichthyosaurs—yet this may not mean that the adults were cannibals. These tiny skeletons within large ones probably are the remains of unhatched young. Like the wading dinosaurs, the mother fish lizard kept her eggs within her body, where the little ones developed and hatched.

Such perfect fitness for life in the sea was not reached in a few short centuries. The ancestry of fish lizards goes back to the time when Dimetrodon and Eryops dwelt on their Permian delta, for skeletons

found in Triassic strata are those of fully formed swimmers, even though their flippers do suggest legs and their tail fins apparently were narrow.

Ere land-dwelling reptiles were firmly established,

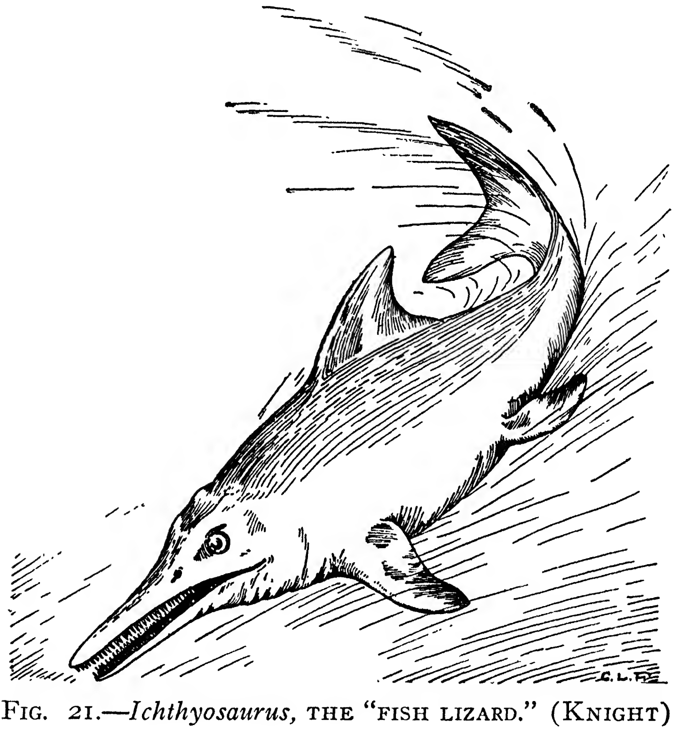

FIG. 21.—*Ichthyosaurus,* THE "FISH LIZARD." (KNIGHT)

some of them thus returned to the water. A few were contented with streams and lakes, but the majority found their way to sea. There they found abundant food and kindly surroundings which permitted variety

of body as well as abundance. For though marine reptiles never equaled their terrestrial relatives, they by no means were limited to the fish lizard pattern. Some developed long necks and others, thick ones; slender bodies swam beside broad. Most powerful of all were the predatory Mosasaurs, which were both the longest of marine reptiles and the first of their kind to be carried to law.

In 1776, a major stationed in the Dutch town of Maestricht found some fossil bones in one of the subterranean quarries which for centuries were worked not far away. The post surgeon also took to collecting, paying the quarrymen for their finds. In 1780, some of the men found a large skull, buried in a rock that they had blasted from a cavern. They at once sent for the naturalist-doctor, who directed them during the skull's removal, worked it free from enclosing limestone and set it up among his most precious specimens. But he soon found himself in trouble, for the Canon who owned the land above the quarries asserted his right to the fossil. The surgeon denied it and the Canon went to court: when the Chapter supported their reverend brother a decree was entered against the collector, in which he lost both the skull and the costs of the lawsuit.

Yet the Canon did not keep his treasure. In 1795, the French besieged Maestricht; and so famous had the fossil become that the general in command ordered his gunners to spare the house that was known to contain it. Suspecting the cause of such special favor, the Canon hid the skull elsewhere. Yet the general was not to be

thus thwarted: when the town surrendered, he offered a reward (said to have been six hundred bottles of wine) for discovery and surrender of the desired specimen. Squads of soldiers ransacked the town, and soon a party of thirsty grenadiers established their right to payment. The fossil, delivered to the army Commissary, was sent to the Museum of Natural History in Paris—and there it is preserved to-day, a part of the spoils of the French Revolution.

Though the Mosasaur's skull was thus mishandled, the living animals tolerated no trifling. The smallest species was eight feet long, while the largest ones were more than forty. They had lithe, slender, muscular bodies, followed by long, compressed tails. They lacked the fleshy fins of the Ichthyosaurs, and their legs had become flippers instead of paddles. Their heads were large, flat and pointed, with eyes of only moderate size. Rows of sharp teeth extended to the palate, while the lower jaw had a special joint which allowed the mouth to spread enormously. Thus the Mosasaur could swallow big fish as well as smaller ones, without troubling to bite them to pieces.

Though their bones were discovered in Europe, Mosasaurs were most abundant in the sea that reached northward across Kansas during the Cretaceous, or Chalk Age. There they swam, fought and mated, following schools of defenseless fishes, yet attacking even the savage Portheus, whose blunt head was armed with teeth hardly less dangerous than those of the Mosasaur. Doubtless these fishes evened matters by preying on

the young of reptiles, or devouring the bodies of wounded adults.

For those shallow, blue Cretaceous waters lacked even the false appearance of peace that one finds at the surface of modern oceans. Mosasaurs cruised them in search of prey; toothed fishes pursued their smaller cousins. Here and there swam giant marine turtles, whose leathery shells were twelve feet in length while their heads were an inch or two more than three. Broad paddles carried them through the water, while hooked beaks took the place of teeth. They sought the shore only to lay eggs, which were put in holes and covered by sand. Such nests were sought by terrestrial reptiles—and perhaps by egg-sucking shore birds.

In bays and open waters were schools of other aquatic reptiles. In some positions they suggested sea serpents: in others, agile, leathery turtles. Their bones, of course, resembled neither—which may account for their name of Plesiosaurs, whose meaning is "almost lizards."

Though the first Plesiosaurs were short-necked and stocky, their Chalk Age descendants were not. Their bodies had grown wider and more flattened, yet their arrow-shaped heads rose upon necks ten to twenty feet in length, and their tails were proportionately long. When prey was located, the long necks reached out to capture it; but if an enemy approached, the reptiles swam away with astonishing swiftness. For what once had been legs and feet had changed into broad, strong paddles in which each toe was a long series of

bones. Even the Ichthyosaur flipper was no more perfectly fitted for swift progress through the water.

Being carnivorous, the Plesiosaurs ate either reptiles or fishes, though the latter were their favored diet. Gulping their food, without attempting to chew it, they had to find some aid to digestion. Thus they swallowed considerable numbers of stones, which lay in their stomachs and aided them in grinding the bony and scaly meals. Such "gizzard stones" often are found beneath the ribs of fossil Plesiosaurs, recording the wanderings as well as the table manners of the reptiles with which they were buried. Thus one Plesiosaur who died in Kansas contained stones that were swallowed in North Dakota, and others were equally ambitious travelers.

CHAPTER XI

WHEN REPTILES FLEW

ONE day in the year 1784, a man working in a German quarry found a fossil animal, whose bones were long and very slender. No one seemed to know much about it, though one writer did announce that the remains belonged to "one of the vertebrated animals that in ancient times inhabited the sea."

In 1810, the specimen was examined by the French anatomist Cuvier, who probably knew more about bones than any other man then alive. Cuvier found that it represented a kind of reptile which simply couldn't have lived in the sea, since its forelegs were much like those of a bat. Other specimens even preserved impressions of batlike wings, with never a trace of flipper or fin. Because much of each wing was borne by one finger the queer reptile was named Pterodactylus, or Wing Finger. The whole group to which it belongs generally are called pterodactyls.

Pterodactylus himself was a little fellow, barely eleven inches in length from the tip of his beak to his stubby tail. Since his head was longer than his neck, and his neck longer than his body, he appeared —and perhaps was—rather topheavy. When flying, he must have shoved his head back between his shoul-

ders, stretching arms and fingers to support his wings. All in all, he must have looked a good deal like a tiny model of the dragons with which European noblemen used to decorate their shields.

Not many years after the German discovery, other winged reptiles were found which showed remarkably varied characters. Some were no larger than a swallow, while others had wings broader than a condor's. One type kept fairly close to its ancestors, retaining the long tail and teeth of typical reptiles, while another developed a pointed beak and allowed its tail to dwindle almost to nothing. By tracing these changes, one German scientist decided that the pterodactyls were connecting links between reptiles and birds.

In this he undoubtedly was mistaken; but his comparisons helped others to understand pterodactyl habits. For birds are related to reptiles, and it is not surprising that when both took to the air several similar structures developed. One of these is the beak, which in both groups became toothless. Another is the system of air chambers which penetrates the bones of both birds and pterodactyls. These, of course, reduced the weight and made flight possible. In some of the largest of pterodactyls, bones almost as large as those of an ox still had walls little thicker than cardboard, while the whole animal weighed but thirty or forty pounds.

But just how did these reptiles fly? Doubtless some of the smallest ones flapped their wings like bats, but for the bigger kinds such flight must have

been impossible. The pterodactyl skeleton has no keeled breastbone such as supports the flying muscles of birds. Without such support the muscles must have

FIG. 22.—*Pterodactylus,* AT REST AND IN FLIGHT. (SEELEY)

been small—too small to move the broad wings more than a few times per minute. And how could that keep the creatures in motion?

The answer is that it probably didn't. Many a bird

soars or glides, and the same method was open to reptiles. If a start could be secured by leaping from a cliff or tree top, so much the better; a few wing flaps, plus careful tilting to meet air currents, would keep the creature aloft over long distances. Progress became a combination of jumping, gliding and true flight. By one means or another, the strange reptiles escaped their enemies—or, feeling hungry, swooped down upon schools of fish, snatched their prey in beak or jaws, and soared back to their reefs or perches. Perhaps some of the smaller species crawled about in search of insects, eggs, or even young pterodactyls whose parents were away hunting.

Of the homes of these reptiles we know nothing. The fact that they flew may mean that they built crude nests and gave their offspring a certain amount of parental attention—even though that is not the common way of reptiles. More probably, a nest was made and eggs were laid in it, from which young reptiles were hatched that could shift for themselves.

We have said that there were two general types of pterodactyls: those with teeth and long tails, and those with beaks and very short ones. One of the best known of the former group was the grotesque Dimorphodon, with a total length of forty inches. Of these, twenty were tail and eight head, leaving but six inches each for neck and body. The suspicion that pterodactyls glided as well as flew is supported by the instep

bones of this genus, which are well fitted for leaping, an essential part of a glider's take-off.

Pterodactyls appeared late in the Triassic period and during the succeeding Jurassic did not wander far from Europe. But in Cretaceous times they reached North

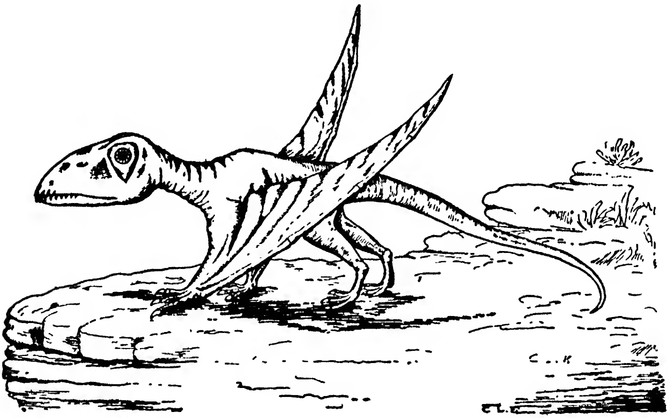

FIG. 23.—*Dimorphodon,* A TAILED PTERODACTYL. (SEELEY)

America and were abundant on the shores of the sea that flooded Kansas and adjoining regions. One skeleton from the western chalk has a wing spread of nineteen feet, four inches, and a skull that is about six feet long. Part of this is a bony crest that balanced the beak during flight, while the sockets of huge, goggle eyes are thought to mean that the reptile did its hunting in twilight—a sort of gigantic Mesozoic owl with skin on its wings instead of feathers.

One strange puzzle presented by pterodactyls is their abrupt appearance in the geologic record. They show no gradual progress from a simple ancestor: full-fledged and specialized, they suddenly enter the sediments of Triassic Europe. From all that the story of their fossils tells, they might have been like the mythical monsters of Greek natural philosophy, which sprang into being from sun-warmed earth, without forebears of any kind.

Yet new animals do not just appear: somewhere they must have ancestors. That of the pterodactyls must have been a land dweller—yet not any that is known from America or Europe. The likeliest remaining continent is Asia, which achieved a degree of stability while its neighbors still floundered in water, and thus offered a chance to creatures that would have been most unwelcome elsewhere. Here, at least, is a clew—and fossil hunters have proved good detectives.

CHAPTER XII

BIRDS THAT HAD TEETH

THE same fine muds that entombed Pterodactylus settled upon the bodies of many other animals, encasing them in layers of buff limestone. That limestone was (and even yet is) used in printing maps and pictures. Hence many quarries were opened, from which workmen gathered both slabs and fossils. The picture of many a Jurassic animal was drawn on the stone that once lay above it, and from that stone was printed upon paper.

Some of these animals, such as king crabs and jellyfishes, were typical creatures of the sea. Others lay or burrowed in the mud, while many were washed into shallows after their death. Some of these came from the open water, while small dinosaurs, pterodactyls and insects were carried into it from the coral islands on which they made their homes.

For years, it seemed that these islands were birdless: that reptiles were their only flying vertebrates. Then, in the summer of 1861, a German quarryman discovered a feather—and that feather was clear proof of birds. A few weeks later a skeleton was unearthed, and in 1877, another. Though the first was headless, the second was complete, even to jaws set with many sharp teeth.

The bones of this bird record its ancestry. The race began as Triassic saurians, closely related to carnivorous dinosaurs. They climbed through the forests on grasping feet, their hips and shoulders covered with long scales, which extended to the tips of their slender tails. As generation followed generation, these scales became fringed and then tufted, finally becoming feathers. They formed a warm, light cover for the body, and enabled the forelegs to serve as wings.

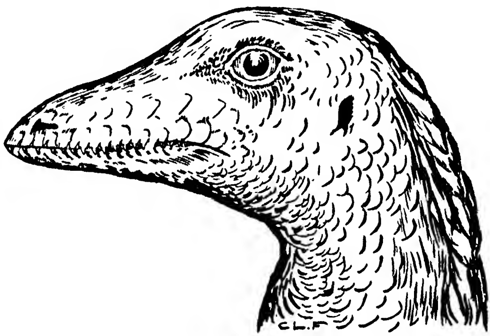

FIG. 24.—HEAD OF *Archæornis,* TOOTHED BIRD OF THE JURASSIC. (HEILMANN)

The sum of these changes was Archæornis, the bird of the Jurassic islands. His size was that of a common crow; his small, flat head bore large eyes, while his toothed jaws were without beaks. Instead of the stubby tail of a crow or pigeon, his tail was longer than the rest of his body, and was set with feathers on either side. The wings bore stout but blunt pinions from which projected three usable fingers. A slight

ruff surrounded the base of his neck, but his body bore only weak tufts or down, which cannot be seen in the fossils.

Archæornis climbed and perched in the trees of the islands, where his mate built a nest of fronds torn from cycads. Both flew to the mud flats to feed, flapping their wings violently at the take-off, but ending their flight with a glide. Returning must have been a more difficult matter, for there were no trees from which to leap, nor rocks to furnish a firm footing. Perhaps Archæornis varied his diet of worms, crabs, and stranded fish with the safer fruits and seeds of trees, which provide food to most of his descendants.

For our next glimpse of birds with teeth, we must go to the Chalk Age sea of Kansas. There, on cliffs to which pterodactyls clung, nested birds that looked like small gulls and like them, swam and dived for fishes. Thus they made use of the teeth that armed the backs of their jaws to keep half-swallowed fish from escaping, while their pointed beaks served in capture. If their habits were as greedy as those of gulls, they also flew screaming and fighting along the beaches in search of carrion thrown up by the waves. A gull is graceful but not very pleasant, and Ichthyornis may have been no better.

Yet in spite of their quarrelsome dispositions, the birds avoided one of their neighbors, whose nesting grounds were the low, moist islands that lay near shore. For though he could neither fly nor walk, this bird was a swift and powerful swimmer, while his toothed beak

could inflict ugly wounds on either scaled or feather annoyers.

Hesperornis—the "western bird"—as this ancient dweller of Kansas has been named, measured five feet from his beak to the tip of his toes. His body was long and slender, his wings were so small that they were mere remnants, and his legs were so placed that they and the feet could be used only in the water. Doubtless there was a time when his ancestors had been normal, flying birds, with both wings and legs in their proper places. Then they took to the water, and there lived so well that the neglected wings very nearly vanished.

Of course, Hesperornis did not suffer from his lack of wings so long as he remained in the water. There his strong, webbed feet rowed him along at the surface; and when he dived for a fish, they forced him toward it with the speed of an arrow. Once caught in that long beak with its rows of teeth, the victim had slight opportunity to wriggle free. It was seized and swallowed in a single gulp, as the big, fierce diver returned to the surface.

Yet the skill and speed of Hesperornis deserted him the moment he ventured on shore. With some trouble he could sit upright, jerking his head to and fro in efforts to be alert and to keep his balance. But the legs that served so well for swimming were utterly useless if he tried to walk. The best he could do was to lie down and wriggle, with his feet projecting helplessly behind.

But did Hesperornis often go ashore? Perhaps he did at the season for breeding, yet even that seems to be doubtful. The modern grebes, also fishers and divers, build floating nests in reedy shallows—and may not Hesperornis have had similar habits? It is not hard to picture a colony of these divers, scattered about

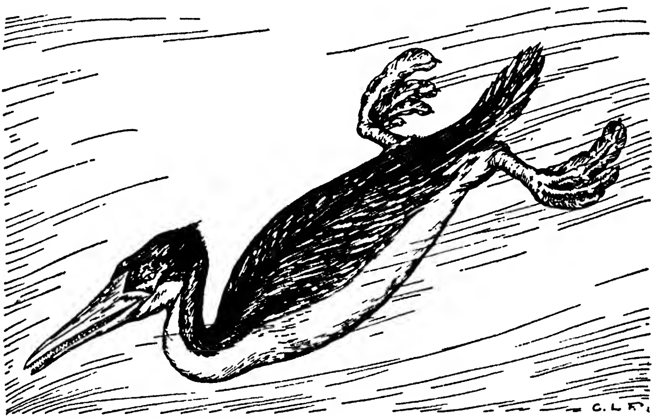

FIG. 25.—*Hesperornis,* THE TOOTHED CRETACEOUS DIVER.

a plant-filled bay. The nest would be built by both parents, but the task of brooding was left to the females, while the males fished or sang rattling, raucous love songs. Now and then, their mates joined them, leaving their eggs to develop by the warmth of the sun, which beat down fiercely on the Cretaceous waters.

In such surroundings, Hesperornis was safe. His nest was hidden from thieving shore birds, and was

beyond the range of large swimming carnivores. He had ready access to deeper water where schools of fish were to be found; while the fact that his mate could leave the nest removed all need for bringing food to her. Not till the eggs were hatched did care become a constant necessity. Even then it did not last long, for the young Hesperornis fledglings soon learned to swim and to follow their mother in fishing.

But what was the goal of such specialization? The one we already have learned to anticipate. Hesperornis appeared during the Cretaceous, and his kind had vanished ere the period closed. Neither speed, nor habit, nor structure saved him—nor do attacks of enemies explain his decline. For they, too, were approaching extinction as the shallow seas slowly emptied, and broad marsh lands became high. The earth was entering a new era, whose conditions the specialized could not tolerate, and from which they seemed unable to flee. And though that is a poor explanation, it is all that we can give to-day.

CHAPTER XIII

NEW CONQUESTS OF LAND

IN the changing world which Hesperornis and pterodactyls found so hostile, new animals waited to achieve dominion. They had waited, indeed, through the Age of Reptiles: for even before dinosaurs made their appearance, there were prophecies of a new and abler race, the one we know by the name of mammals.

Mammals are those creatures which, in everyday English, are spoken of as *animals,* to distinguish them from insects, snakes or birds. They have warm blood; their bodies are clothed in hair; they nurse their young on milk which is secreted by glands located in the skin. Some of them walk on two legs, talk, and are called men, while even the lowest forms show superiority over other vertebrates. Their rise to power, in place of the reptiles, joins with the elevation of plains and mountains in marking the beginning of a new geologic era—that of the Cenozoic, or "recent life."

The ancestry of mammals, like that of every other important animal group, has been a subject of uncertainty and argument, in which opposing scientists have labored earnestly to prove (or disprove) rival theories. Some thought that mammals arose from reptiles, but Huxley and his followers maintained that they came

directly from early amphibians, without an intermediate stage. Time and fossils have proved Huxley wrong, even though we don't yet know which reptile deserves the honor of being our ancestor. But at least, we are familiar with the group to which it belonged, and with

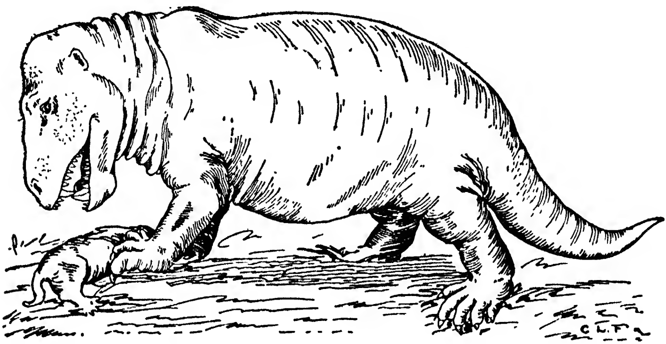

FIG. 26.—A PERMIAN DOG-TOOTHED REPTILE, *Cynognathus*. (GREGORY AND DECKERT)

the conditions which they met in their fight for existence.

It was in the Permian and Triassic rocks of South Africa that these near-ancestors of ours left most of their remains. Their teeth were so like those of some mammals that they have been given the name Cynodontia, or "Dog-teeth," yet their bones were those of primitive reptiles. From this combination of primitive bodies, advanced teeth, and a natural capacity for change, arose a new and more complex kind of animals.

The step was taken in southern Africa, some two hundred and fifty million years ago. Some of the

smaller cynodonts developed more efficient hearts; their scales lengthened into hair; their brains became larger and better; they lost the rearmost bones upon each jaw. Probably their bodies became even smaller, so that they could take to climbing among vines and trees. Doubtless they also began to travel: to wander about in search of food and safety, or to find conditions that were pleasant for living.

Nor was that an easy task during the late Permian and early Triassic. Uplift of land in Texas and New England was but a minor part of the world-wide revolution that closed the Paleozoic era, and reached its height in the southern hemisphere. There, lowlands were turned into windswept deserts, while vast glaciers invaded the tropics, plowing their way within twenty degrees of the Equator. Their advance was heralded by cold winds, frosts, and winter blizzards, in which reptiles perished and even the newly risen mammals had need for all their intelligence and agility. Thanks to the warmth of their blood, they could move rapidly even when weather became cool, while their coats of hair helped conserve heat. By means of milk, they could nourish their young even while moving—whether those young were born or hatched from eggs. At first, the latter was the prevailing method: a heritage from reptilian ancestors that is retained to-day by the echidna and duckbill. When the habit of egg-laying was lost, young were born partly developed, to be carried and nursed in the pouch of the mother. Mammals increased

their chance of survival in a world groaning beneath cold and glaciers.

Thus they lived and changed, until Mesozoic ages once more brought quiet and warmth. Yet mammalian prosperity did not come with them. So far as we know, Mesozoic mammals were small, few exceeding the size of a rat. Through most of the era, they clung to trees, eating seeds, fruit or insects—and perhaps the eggs of small reptiles and birds. Yet during those hundred forty millions of years, dinosaurs achieved miracles on land, pterodactyls ruled the air, and several types of voracious reptiles achieved dominion in the sea. The earth was hospitable to life, which responded with size, variety and abundance. Yet the newest group of animals, with the vigor and plasticity of youth on their side, with bodies effectively maintained and nourished, and with brains better than those of their neighbors, remained in furtive arboreal hiding. Why did they, the favored, thus fail to advance?

The answer to this question is a matter of size. Mammals had sprung from small ancestors under conditions hostile to bulk. Elsewhere, sizeable reptiles survived. In the less rigorous regions of the northern hemisphere, many of them continued to grow; and when mammals finally reached Europe and America, they found the ground in the possession of large, agile reptilian carnivores. In the Peabody Museum, at Yale, there is a series of tiny jaws with teeth belonging to early Jurassic mammals whose home was a forest in the present Wyoming. With them were

found several dinosaur bones and one tooth of the huge, fierce Allosaurus. It is a curved weapon six inches long, with sharp point and serrate edges—a tooth appropriate to a carnivorous reptile thirty-four feet long. It also shows why, in those broad, lush, well-watered lowlands, mammals clung to their homes in the trees, and to habits which brought no conflict with reptiles.

That the fault was not one of mammalian weakness is shown by events of the Cenozoic. Scarely had the dinosaurs vanished when their places were taken by hordes of these creatures, some of which soon achieved large size. Never has the earth seen a change in life so rapid and so thorough as that which came with the death of great reptiles and the first expansion of the repressed mammals.

Yet the beasts of the early Cenozoic were not like those that we know to-day. Though they had forsaken the forms of their arboreal ancestors, they still were too primitive to possess the specialized organs of modern mammals, or to belong to groups that are living to-day. They might—and did—resemble modern creatures, yet lacked their efficient, specialized bodies. Not one archaic mammal had feet like those of the horse or deer, so well fitted for swift running. Their flesh eaters lacked retractile claws and agile limbs, or the cleverly useful paws of the bear. Nor did the herbivores have teeth which could crop grass, or chew coarse, resistant herbage.

Both primitive structure and mixed resemblance may

be seen in such a beast as Phenacodus, which ranged the West in small herds near the very dawn of the Age of Mammals. His teeth suggested that he might be hoglike: but when skeletons at last were found, they showed a very different creature. Some species were as small as a fox, while others exceeded the size of the goat. All had clumsy, five-toed feet whose

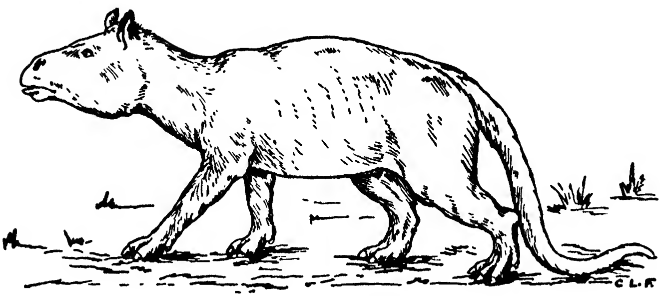

FIG. 27.—*Phenacodus,* AN ARCHAIC HERBIVORE. (SCOTT)

hooves had the form of nails, and all trailed long, slender tails behind their highly arched backs. From a distance, they must have looked like huge awkward cats which had traded their heads for those of sheep and had chosen the manners of swine. Empedocles, a Greek philosopher, held that animals were formed by helter-skelter assembly, so that many contained organs which did not fit. He would have welcomed Phenacodus as proof of his queer theory of natural creation.

Upon these bizarre beasts fed flesh eaters that were not true mammalian carnivores. Most of them had

large heads, long tails and short, weak legs. Some looked and perhaps behaved like wolves; others suggested bears, civets or otters. The most important group resembled hyenas, and found a scavenging life successful. Not only did they outnumber many more active and graceful species; they outlived all other archaic mammals and developed somewhat better brains. Plainly, the habit of eating carrion does not always lead to degeneracy, nor diminish its followers' chance of survival.

The largest of archaic mammals belonged to a second group of herbivores whose name, Amblypoda, means "Blunt feet." Beginning with bodies much like those of Phenacodus and his relatives, they achieved size and specialization of habit in spite of archaic anatomy. Coryphodon, of the early Eocene, had the broad body, short legs and stubby feet of a hippopotamus, whose place he doubtless took in American rivers. His broad, blunt head was armed with a single pair of sharp tusks which rival males doubtless used when fighting.

He was followed by Dinoceras, the "Terrible Horn," a beast which piled an amazing surface of specialization upon a purely archaic foundation. Roaming the savannahs of Wyoming during the later centuries of the Eocene period, Dinoceras reached a height of seven feet, with the body and legs of a small elephant. Yet his long, flat head suggested that of a rhinoceros—or would have, had it not borne six blunt horns instead of one or two sharp ones. They were covered, how-

ever, only by skin: a defect partly compensated by the two long tusks which extended downward from the upper jaws and were sheathed by extensions of those below. Both they and the horns were larger in males than females, forming excellent weapons against packs of false wolves (creodonts) that sought to capture Dinoceras calves, or to pull down sick or wounded adults.

Yet under this huge, armored skull lay two very imperfect structures. While Dinoceras enlarged his body and head, his chewing teeth scarcely changed, and so became smaller and smaller in proportion to his size. His brain did a little better, yet even it failed to keep up, or to acquire the intelligence one should suppose was needed to manage his ponderous bulk. Man, whose intelligence rarely is oppressive, has three per cent of his weight in brain; that of Dinoceras was but one four-thousandth of his whole, hulking body, and was poorly equipped with those parts which are the seat of what we call intelligence. He could think, of course, but he preferred to feel or to govern his acts by unconscious reflex.

Even before Dinoceras appeared, the world saw an influx of more able mammals. They reached America early in the Eocene epoch, as immigrants from the home land of Asia; they continued in wave upon wave of migration and in the development of races already established. Ere half of the Eocene had passed, archaic mammals were in minority, while in the suc-

ceeding Oligocene epoch, only the hyena-like creodonts survived.

Though Oligocene rocks (the name means "slightly recent") are found throughout the world, they are best known from the White River formation, in the Bad Lands of South Dakota and Nebraska. When these rocks were being deposited, the country which now is a waste of barren hills was a broad, low prairie across which wound shallow rivers laden with mud. The climate varied though passing centuries, so that lands at one time studded with lakes might be dry and wind-swept at another. Yet always there remained abundant pasture, supporting great herds of herbivorous mammals—and they, in turn, fed the carnivores. When an animal died, its body or bones were very apt to be buried in mud or covered by drifting dust or sand. As a result, the Bad Lands are a huge Oligocene cemetery whose hills sometimes are strewn with bones and teeth that have been washed from the soft strata.

Among these abundant fossils are the remains of small, three-toed horses, descendants of the earlier Eohippus. They probably ran through wooded lowlands, leaving barren areas to the little, humpless camels, also derived from Eocene ancestors. Herds of oreodonts, herbivores which looked a bit like Phenacodus, must have been everywhere, for their remains are the commonest of Oligocene fossils. One type, with a skull so deep that it suggests a monkey's, seems to have lived in swamps; while another, which affected a cat-

like tail and claws, perhaps found shelter and food in woodlands. Still a third preferred barren, dusty uplands, where it could run freely in large herds.

With the abundant oreodonts lived several kinds of rhinoceros. The commonest were small, hornless animals with the build and habits of later horses. Others, larger and less active, fed in the forests, while a few species with heavy barrel-shaped bodies and short legs spent their lives in the swamps that fringed most of the Oligocene rivers. They too lacked horns, but possessed tusks that served as weapons.

North America, which claims the largest pterodactyls and the fiercest dinosaurs, was not the home of the biggest rhinoceros. That honor seemed to belong to Europe—until in 1911, a British scientist working in the hills of Baluchistan, found a few bones of a beast which seemed to be a rhino, yet was larger than any living elephant. He named it Baluchitherium, the "Beast of Baluchistan," and hoped that other fossils would tell more about it.

They were found eleven years later by an American, Walter Granger, of the American Museum of Natural History. In southern Mongolia, Mr. Granger uncovered three partial skeletons of Baluchitherium, one of which preserved the skull. With the utmost care, its three hundred sixty pieces were removed, packed and sent to New York. There a skilled preparator and his assistants spent three months putting the bones together—but in the end, they had the satisfaction of knowing that they had reconstructed both a new and strange

kind of rhinoceros, and one of the largest of land mammals.

FIG. 28.—*Baluchitherium,* THE LARGEST RHINOCEROS. (OSBORN)

In a world which counts a draft horse large, and a nine-foot elephant as a giant, Baluchitherium seems almost unreal. He was twelve or thirteen feet high at

the shoulder: by lifting his head and stretching, he could nibble twigs twenty feet from the ground. Thus he was both taller and heavier than the African elephant, the largest of modern land mammals. Professor Henry Fairfield Osborn, who described his remains, pictures Baluchitherium as a gigantic browser wandering in small herds among the fertile savannahs of ancient Mongolia during late Oligocene and early Miocene times, protected from enemies by his height and his speed, which were greater than those of any elephant.

Those savannahs, not many millions of years before, had been ruled by beasts more rhinoceros-like than Baluchitherium, yet of very different ancestry and nature. They weighed two or three tons, with thick, deep bodies and massive legs. Their heads were broad and very long; each bore a thick, paddle-shaped horn rising twenty-eight inches above the nose. Like the horns of Dinoceras, it was covered by skin—yet backed by the bulk of its owner, it made a strong and dangerous weapon. With it the enraged titanothere ("Giant Beast") could batter, push or toss an enemy, even one of his own ponderous kind.

Ancestral titanotheres had been born in Asia: light-bodied animals smaller than sheep, with four toes on their front feet and three behind, and a tiny knob of bone above each eye. As epochs passed, some stayed in the Mongolian homeland while others wandered into North America, where their remains were preserved as early as the Eocene. Meanwhile, those knobs moved forward and grew into horns, some of which were

single while others were paired. The skull also became wide and very strong, its upper surface gently saddle-shaped. It was supported by a thick neck and strong muscles whose attachment made a hump on the shoulders—and the trunk and legs grew in proportion. Thus arose the last and finest of the titanothere race—true giants weighing more than most captive elephants, with heads a yard or more long, and horns never less than a foot in length. In most species, especially of North America, those horns were paired, and spread broadly from the nose, to be used in goring or tossing opponents.

Despite their bulk, the titanotheres depended on their lips for browsing, since their front teeth had become almost useless even though the rear ones had become large grinders fit to crush leaves, shoots and tender twigs. Like Dinoceras, they must have been very stupid, managing their large frames by means of a brain little larger than a man's clenched fist. Some have thought that this lack of intelligence brought their extinction; others maintain that they could not get enough to eat, and thus starved in the midst of plenty; while some have suggested epidemics of disease, spread by the rising hordes of insects. Which idea is true, we do not know; yet our ignorance does not obscure the fact that titanotheres became extinct with surprising rapidity, long before the end of the Oligocene epoch.

In the valleys favored by titanotheres and oreodonts, there also lived herds of "giant pigs." Actually, most

of these animals were smaller than the modern domestic hog, and so are better known by their name of elotheres. But with the passage of time, they too became larger, until the last millennia of the White River

FIG. 29.—TWO TITANOTHERES OF OLIGOCENE MONGOLIA. (OSBORN)

Age saw the appearance of species whose skulls were as long—though by no means as wide—as the heads of the triumphant yet vanishing titanotheres. Each skull bore bony extensions above the mouth, while others projected from the jaw beneath it. Powerful tusks

resembled those of the wart hog, but were put to a rather peculiar use. Like true pigs, the elotheres doubtless ate plants, flesh or carrion, but their favorite diet seems to have been roots. So persistently did they dig for them, that the tusks of every specimen bear deep grooves worn by the dirt-covered roots as the beast pulled them from the ground. We need not rely on comparison alone in determining the food of fossil mammals.

Compared with the large and abundant herbivores, Oligocene flesh eaters seem small and weak. The largest were survivors of the archaic creodonts, with large heads, thick bodies and rather poor feet and teeth. Except for a few monsters in Mongolia, they were too weak to prey on the herds of titanotheres, and were too slow to capture horses, camels or oreodonts. Like their Eocene ancestors, they probably had the habits of hyenas, feeding upon dead bodies, or killing aged or injured animals. Even the wolves were too small to hunt the larger species, while the commonest of the saber-toothed "tigers" were no larger than the modern lynx. Truly the Oligocene was an age of luxury for plant eaters, with few enemies to plague them and none to threaten their racial existence. When they became extinct in spite of such freedom, the fault must have lain in their own bodies, or in rarely hostile physical conditions.

CHAPTER XIV

A QUICKSAND'S TREASURE

DURING the late Oligocene, the Isthmus of Alaska sank under water, so that migration of mammals from Asia ceased. But as the Miocene or "Middle Recent" epoch dawned, land connection was again established and animals wandered freely across. The climate also remained mild: forests of palms, camphor and cinnamon thrived in central Europe, while oaks and evergreens covered northern Greenland. Warm-temperate forests reached into Montana, and were buried by the clouds of volcanic ash which settled where Yellowstone Park lies to-day. Irises and roses bloomed on plains now given over to sage and bunch grass.

Yet not all was lush and easy. There were dry regions, swept by wind storms, where herds of oreodonts were buried as they huddled for shelter from the biting sand. There were broad plains, barren and alkaline in time of drought, across which bands of herbivores staggered, panting, in search of water. When they found it, they were too crazed with thirst to pause: in maddened rushes, they hurled themselves into ponds or rivers, trampling each other under foot or sinking into treacherous quicksands, to drown where they

sought to save their lives. Such sands became veritable bone-beds, filled with the remains of thirst-mad mammals.

The greatest of these Miocene quicksands was discovered in 1877 by James Cook, a pioneer ranchman and frontier scout. It lay in two small, flat hills not far from the town of Harrison, Nebraska, in the valley of the Niobrara River. The rock is a soft, buff-gray sandstone laid down in an eddy of the ancient Niobrara, when its floor lay almost as high as the hills, and the present valley was still uncut. In the ever-shifting sands of that eddy, so many mammals were drowned and buried that, though fossils have been collected for fifty years, enough remain for all future museums. Dr. W. D. Matthew estimated that in one hill alone there were seventeen thousand skeletons—no less than three million four hundred thousand bones. Other millions lie in the second hill, while any estimate of the original numbers must include those washed out and away as the Niobrara dug its present broad valley.

Of these seventeen thousand skeletons, more than sixteen thousand belong to a small rhinoceros named *Diceratherium cooki,* in honor of the scout who discovered the bone-bed, and owned the ranch upon which it lay. Diceratherium was no heavier than a good-sized hog, though his legs were longer and thicker. His two horns were borne on his nose, but side by side like those of titanotheres. His race must have ranged the plains of Miocene Nebraska in herds almost as large as those of the historic bison; traveling far in search of forage,

they were the first to feel the pinch of drought. At first they sought creeks and water holes, but as these went dry they turned toward the river, with results that we already have seen. Rushing into the desired water, they were caught in the treacherous quicksand

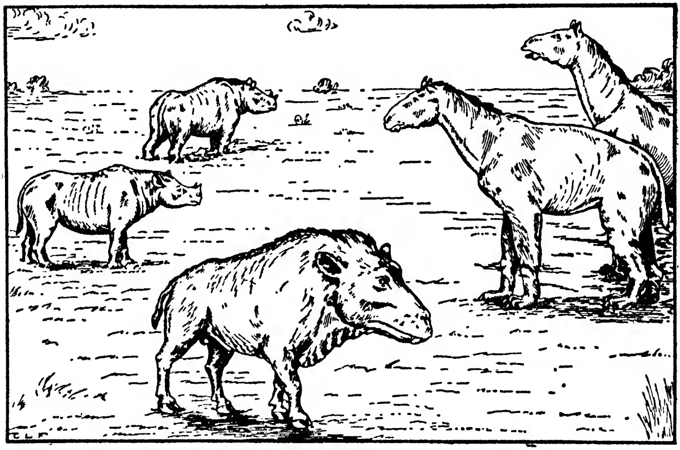

FIG. 30.—BEASTS OF MIOCENE NEBRASKA.

Two-horned rhinos, the giant pig, *Dinohyus,* and the clawed herbivore, *Moropus.* (Peterson)

and drowned. As flesh decayed, the moving sands tore their bones apart, to settle hit-or-miss in tangled masses. One block with an area of forty-four square feet contains four thousand three hundred bones, and only those of the skulls are joined together.

Into this same quicksand, but in much smaller numbers, came the strangest of all hoofed mammals. Moropus was about equally related to the horse, the tapir,

the rhinoceros and the titanothere; he managed to look a bit like all of them, with peculiarities of his own thrown in. His head and neck were horselike; the thick, sloping body and stubby tail suggested a tapir; the stocky legs had the size and structure of those of modern rhinos, though the forelegs were very long. His molar or grinding teeth were those of titanotheres, while his front teeth should have belonged to a ruminant. To complete this body of mixed resemblances, the toes bore long claws like those of Jefferson's ground sloth, instead of the hooves which properly belonged to them. How those claws came into existence, and what use Moropus found for them, are but two of the large bundle of puzzles which surround this queer, contradictory beast.

Doubtless Moropus was much less abundant than Diceratherium, for there are but five hundred of his skeletons to sixteen thousand of the little rhinos. Perhaps, also, he became less thirsty: his form suggests that life was spent chiefly in the river valley, or on wooded, gentle hills at its edge. There he would have no cause to suffer—and only when caught in the mad stampede of a herd of rhinos would he rush into the treacherous quicksand. Even that need not happen often, for Moropus was too heavy and too slow to be carried along in any but the largest herds.

The third animal drowned in the quicksand was an elothere, or giant pig. Dinohyus was somewhat larger than the modern bison, with two-toed feet like the bison's and a large hump above his shoulders. His

head was large, with a long muzzle and thick, powerful tusks. They and indeed all of the front teeth were those of a carnivore, rather than of an animal that fed on plants, though the molars were of omnivorous type. Probably Dinohyus had the tastes of a pig or bear, eating flesh, fruits or roots, as chance might offer. Yet he was far more savage than the wild boar, and much better fitted to pursue and kill prey than is even the grizzly.

Again, we are uncertain whether Dinohyus was really rare, or whether he was too wary to be entrapped in the quicksand. In his census, Dr. W. D. Matthew allowed for one hundred elotheres as compared with sixteen thousand rhinos, and even that number may be too large. But if Dinohyus occasionally preyed on herbivores, their blood would provide a measure of moisture, and thus stave off thirst in dry seasons. Or perhaps the big beasts clung to their own favored water holes, from which they drove less able creatures.

Yet sometimes they did come to the eddy, and with Diceratherium and Moropus were buried in its fine, shifting quicksands. But why were these three alone engulfed? The nearby plains were inhabited by oreodonts, three-toed horses, camels, deer, beaver and wolves—yet so far as we know, not one of these was caught in the growing bone-bed. Even when their remains are found in it, they turn out to be battered, water-worn fragments carried down by the current for several miles before they were dropped in the quiet basin. Not one was trapped or buried in the quicksand

that covered so many rhinos, and the awkward bodies of clawed Moropus.

As ages passed—for Miocene time measured millions of years—both the plants and animals of America changed. In place of the tiny gazelle-camel, Stenomylus, whose bedding ground was but a few miles from the Niobrara River, animals appeared which were as large as the llama, with feet fitted for walking on sand. In open woods were herds of Alticamelus—a true member of the camel family, yet endowed with the long legs and neck of a giraffe. Doubtless it shared the giraffe's habit of nibbling leaves borne high upon trees, and thus gave the plains of Miocene Colorado a tinge of the modern African veldt.

This resemblance was increased by the presence of animals which in form, if not in teeth, were elephants. Their ancestors had appeared in Eocene Egypt as small marsh or river-dwelling beasts whose bodies suggested those of tapirs. During the Oligocene they grew more elephantine, increasing in height from two feet to four and one-half, and acquiring both trunks and tusks. They also began to wander out of Africa. By the middle of the Miocene, their descendants had crossed Asia and Canada, and had arrived on the plains of Colorado, South Dakota and western Nebraska.

These early mastodons—the name elephant does not quite fit them—stood five or six feet high at the shoulder. They had long heads and projecting lower jaws, short trunks and four tusks. The upper ones were

slender and downcurved, while the lower were short and chisel-shaped. Trilophodon probably used them to dig plants from the mud of rivers and water holes, so that attractive morsels could be selected by his trunk and pushed back into his mouth for chewing. Some of his descendants would expand those tusks into broad shovels with which they turned up masses of succulent plants, from which only the choicest were chosen and eaten. Their quest for delicacies often led these mastodons into pools underlain by soft, sticky mud into which they sank and were buried. A hard fate for them, it is true, but one which provided excellent fossils which range from the tiny bones of unborn young to the skeletons of aged and giant tuskers.

Though these lazy mud-grubbers did not travel swiftly, they spread from Mongolia to western Nebraska, becoming common late in the Miocene epoch and living on into the Pliocene. One reached a height of seven feet nine inches; another, not so large, had a skull six and one-half feet long. Yet progress did not keep pace with size, for the teeth which lay in those extended jaws were little better than those of the Oligocene ancestor which first left Egypt, and whose jaw measured two feet six inches. Trilophodon continued to rely upon succulent water plants, which could be dug and swallowed with little chewing.

Yet the largest and strangest of early proboscideans dwelt in the lowlands of central Europe, also during Miocene and Pliocene times. Dinotherium, the "Terrible Beast," reached a height of nine or ten feet, thus

surpassing most circus elephants. He was built much like a true mastodon, with thick body and long, massive legs, but his skull was slanting and his trunk short, while his upper jaw bore no tusks. The lower one curved downward so abruptly that its two short tusks turned backward. Unlike those of Trilophodon, they thus were useless for digging, though they may have helped to pull down branches, or hold them while the stubby trunk plucked leaves and twigs. Yet only those that were very tender—for the molars of Dinotherium were the simplest of elephantine grinders. How the great beast lived is something of a puzzle, since his legs were too long for comfortable wading, and his teeth too weak for upland forage. Thus hemmed in by limitations, he failed to achieve wide dispersal, and died as the earth grew cooler and drier.

But let us return to American mammals during the latter part of the Miocene epoch. Along with mastodons there were many rhinos, the commonest being a large creature with barrel-shaped body and short legs. Its habits were those of the aquatic hippopotamus, though it doubtless was less adept at swimming. Horses also were abundant—small grazing and browsing types with legs as slender as those of the deer and almost as fit for speedy running. Though their feet still retained three toes, the middle one was by far the largest and bore the weight of the body.

Dogs, some as small as foxes and others which rivaled the largest bears, were most abundant among the carnivores. The more savage ones hunted in small

packs, pulling down horses, deer and camels. There also were hunting cats, with long legs and slender bodies like those of the modern Indian cheetah. The saber-toothed cats were less active—thick-muscled beasts whose upper canines had developed into long, curved weapons while their lower teeth grew small. They hunted by stalking, relying upon a sudden leap and a few vicious slashes to kill their prey. Their name, Machaerodus, which means "Dagger-tooth," both describes the shape of their canines and implies their favorite method of killing.

Most of these Miocene mammals came from established American ancestors, since immigration sank almost to nothing in the later centuries of the epoch. Surveying them, we are impressed by abundance as well as by strangeness, and we notice this important fact: Though there were many types, such as Trilophodon, which continued to rely on succulent plants, the late Miocene showed a great increase in those that could live on harsher food. Horses, deer, even camels, developed high, resistant molars which withstood the wear of tough stalks and leaves. In this, the horses were most successful, producing teeth which were little but crown, with elaborate folds of hard enamel. Better than any other herbivore, they typify the change from savannah to grassland; from moist glades to high prairies from which soft plants rapidly vanished, and whose forests were reduced to woodlands of increasingly hard and hardy trees. Life again was becoming difficult, and mammals were forced to meet its challenge.

CHAPTER XV

BEASTS OF THE ICE AGE

THE Beastes best knowen in this country are Stagges, Hindes, Goates, Deere, Leopards, Ounces, Lucerns, divers sortes of Wolves, wilde Dogges, Hares, Cunnies, and a certain kind of Beast that differeth little from the Lyon of Africa."

Thus the geographer Richard Hakluyt described the mammals of Florida, in a book written about 1580. His list now looks a bit like fiction, for we know that no leopard ever ran wild in Florida unless it escaped from a zoo or circus, while the southern cougar or puma differeth more than a little from the African lion. But had Hakluyt known of the Flower State's fossils, he might have compiled a list beyond the credulity of even the sixteenth-century Englishman—and that without exaggeration. For who ever heard of plump rhinos near Tallahassee, or bear-dogs and elephants in the glades near Tampa?

Yet greater marvels have been encountered. A rhinoceros with the habits of a hippo is less strange than a reptile with wings—and it seems much more in place in the swamps of Florida than on the high, dry plains of western Nebraska. Elephants in the Everglades are less surprising than herds of tuskers and "totos" plod-

ding across an Alaskan isthmus, on their way to Mexico or the Mississippi Valley. The difference lies in the fact that Alaska and Nebraska have changed greatly since the days of Diceratherium and mammoths, while Florida has remained almost the same. In its damp forests and low grasslands we find conditions like those which surrounded a great many early mammals. They thus suggest rich fossil faunas, even though most of the bones still lie buried beneath the roots of live oaks and palmettos.

Yet their record does not go back of the early Miocene. Even that date is based on finds in one well, which an unknowing owner carefully filled before collectors came to seek fossil bones. The first well-known fauna of Florida lived thousands of centuries after Diceratherium, near streams which carried carcasses out to sea. One may find remains of horses, deer and camels in marine fuller's earth mines near Tallahassee, along with bones of the manatee or sea-cow.

Other pits, from which phosphate rock is dug, contain bones and teeth of the Pliocene Age—the fourth epoch in the Era of Mammals. Workmen digging raw fertilizer find bones of two types of mastodon, mingled with teeth of sharks. The mastodons were derived from four-tusked Trilophodon, which had come from Asia long before. Slowly its descendants pushed on to Florida, followed by the aquatic rhinoceros. Both reached the shores of the Gulf of Mexico long after their appearance in Nebraska—as also did camels, horses and queer carnivores like the bear-dog.

It was in the Pleistocene, however, that the mammals of Florida became most abundant. This period, often

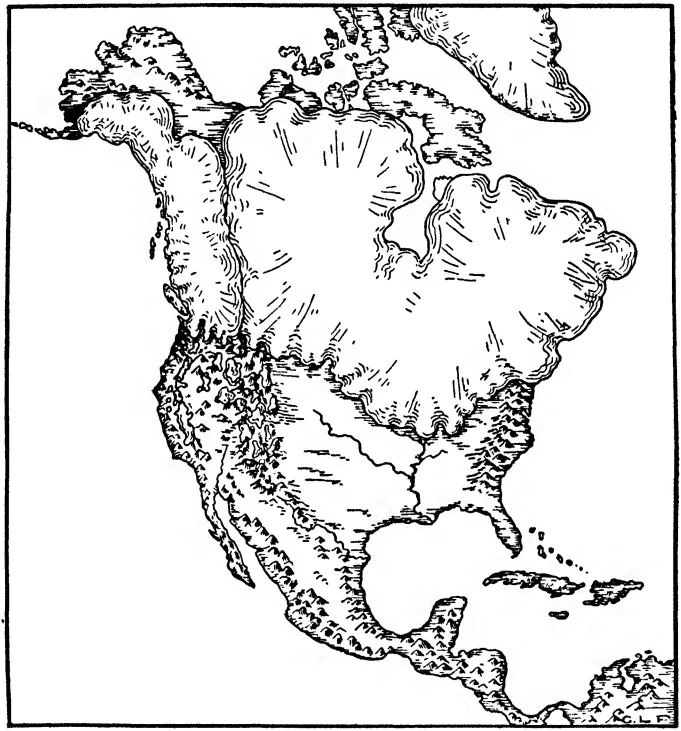

FIG. 31.—NORTH AMERICA AT THE HEIGHT OF PLEISTOCENE GLACIATION.

Coast lines as they are at present. (Salisbury)

called the Glacial, saw the growth of vast ice sheets which pushed southward from Canada, across fertile

lowlands over the low eastern mountains. They halted five hundred miles north of Florida, it is true, but the cold which they brought did not cease with them. Hills of Missouri and Kentucky lay but a few miles from the glacier front, and were the homes of arctic plants and mammals. Those which required warmer climates either became extinct or retreated southward, eventually to reach the low lands of Florida. There, amid forests of live oaks and palms, the giant beaver found refuge when driven from the streams of Iowa and Ohio. Horses, tapirs, camels and bison deserted bleak or glacier-bound prairies for kindlier lands near the Gulf of Mexico. With them came the Columbian and imperial mammoths—true elephants whose nearly naked skins made them more sensitive to cold than were their woolly relatives of Europe and Asia. Even the mastodons, which ranged northward into New York and high on the slopes of the Rocky Mountains, retreated to Florida and there found a shelter in which they survived long after the glaciers had melted.

Stranger than any of these were the great ground sloths, seven to twenty feet in length, with coats of coarse, reddish hair and skins set with small plates of bone. With them was a giant armadillo and its cousin, a glyptodont, whose body was covered with a shell of bone, and whose tail was encased in rings and spikes. All were migrants from South America, whence they had wandered northward during warmer epochs. Unable to endure the glacial winters, they retreated as fast as their short legs and dull brains permitted. Since the

glaciers advanced very, very slowly, they still were able to reach safety, and to carry onward till they reached Florida.

The carnivores of this crowded southland were larger and more savage than their Pliocene predecessors. Strong, swift wolves pursued camels and horses; lions hid in grasses by the trailside, ready to pounce upon their prey. Saber-toothed cats with thick bodies and stubby tails hunted in small packs through the open woodlands. Their chief victims probably were the ground sloths, whose bony skins offered slight protection against the daggerlike teeth of the powerful carnivores. A few savage slashes, a blow or two from a huge forepaw, and all that remained was the business of eating. More active prey might escape by running—but the ground sloths were far from active.

We sometimes think of the Glacial Period as a million years of ice and winter, followed by gradual warming and melting, which still are in progress on Greenland. But such a picture is far too simple. Over much of North America, there were four great epochs of glacial advance, with at least a fifth of minor importance. Between them lay periods of warmth, when the glaciers melted and the climate moderated—even more, perhaps, than it has done at present. During the second mild, or interglacial epoch, plants which now grow in Virginia reached the hills of southern Ontario: ample proof of warm weather.

When plants migrated, animals followed. Masto-

dons, mammoths, horses, camels and a bison with horns six feet in width, followed the melting ice of the Mississippi Valley. Close to the ice front came the moose-deer and musk ox; after the passage of centuries, ground sloths arrived, to be driven back as the glaciers returned. Yet with the next warm epoch they reappeared, along with the mastodon and mammoths, the giant bison and the native horses. Even when the Ice Age drew to its close, elephants, mastodons and ground sloths followed the melting fronts of the glaciers, to dwell again in lands from which the ice had driven them. And there, in forests of pine, balsam and poplar, free from the threat of another eviction, they at once began to become extinct! Clinging to life for a few thousand years, their numbers became smaller and smaller. To-day only their bones remain as records of a long and gallant struggle, which overcame enormous difficulties yet failed as the chance for success appeared.

But what, meanwhile, of the Far West? Had it escaped the ravages of ice, and the shifting hordes of Pleistocene mammals?

By no means. Continental glaciers stopped ere they reached the foot of the Rockies; but in the mountains, ice streams far greater than those of the Alps dug valleys such as that of the Yosemite, and covered the slopes of high peaks. In the low, warm lands along the Pacific coast lived a fauna as rich as that of Florida, and very much better known. Some of the same species that dwelt in inter-glacial Kentucky and Iowa also

found homes in California, there to find other sources of danger, and to fall prey to forces of nature no less fatal than ice.

This fauna was most abundant and left its finest records in the country about modern Los Angeles. Low plains stretched from the sea to the Coast Range, whose higher slopes were covered with snow. Tall grass grew in the open; groves of cypress and other trees broke the monotony of level land. In open woods there were herds of that largest of elephants, the imperial mammoth, twelve to thirteen feet at the shoulder. Smaller bands of mastodons clung to the forests, leaving them only when forced to seek water in pools or streams on the open prairie. Bison with high shoulders and narrow heads fed on the grasslands, along with herds of horses and large camels. Both were descendants of races long established in North America, whence they spread into Asia, Europe and Africa—yet became extinct in their homeland at the close of the glacial period.

Ground sloths, closely related to those of Florida and the Ohio Valley, blundered about in the open woods and across the prairies. They were pursued by the saber-tooth, also much like his brother of the East, and smaller than the giant species of the Pampas. Bands of lions, shaped like those of modern Africa, but almost as large as the Alaskan brown bear, preyed upon horses, bison and camels. There were several species of wolves, while lynxes, pumas and martens hunted in the forests. Giant condors and several lesser vultures

soared the skies in search of carrion, while eagles and owls sought lesser prey and herons fished in ponds.

A surprising and abundant fauna, even though we assume that instead of living as a unit, it shifted through hundreds of thousands of years, with one species replacing another. Yet its remains lie in a few small basins, which preserved them even while they killed, in tar which still captures careless jack rabbits and other animals that venture upon it.

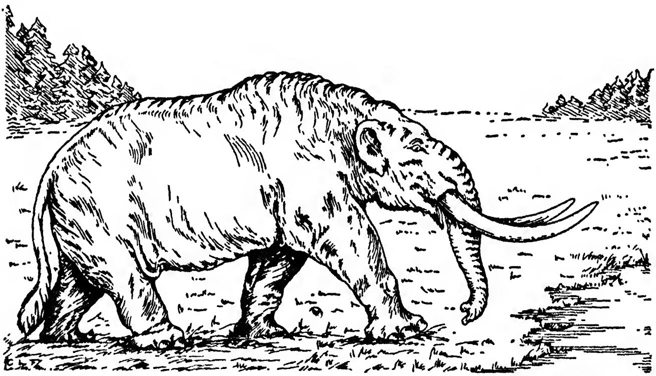

FIG. 32.—A MASTODON OF THE HUDSON HIGHLANDS, IN AN INTERGLACIAL EPOCH. (KNIGHT)

But why should mammals so wary as the mammoth or lion become entangled in natural tar pits? What brought such varied creatures as skunks, horses, wolves and condors to their death in a single sticky pool?

Those pools, though deep pockets of fluid asphalt, are covered with a few inches of water. That water, perhaps, is not very savory; yet it will quench thirst if

only it can be secured without miring. Under conditions of normal winter rainfall, few animals seek to drink it. But dry seasons are another matter, and in time of drought animals still are driven to the tar pools. Some manage to drink and escape; more often, they venture too far, and their bones join those of extinct camels and lions.

The same thing happened during the Ice Age, when there were many more mammals to drink and be buried. Perhaps, also, the Pleistocene climate was periodically dry, with years or decades in which winter rainfall was sparse and that of the summer non-existent. For a time, animals sought streams flowing from the melting snows of the Coast Range; but as they vanished and water holes dried, herbivores rushed to the deceptive tar pools much as the little rhinos had crowded into the Niobrara eddy. After them came carnivores and scavenging birds, until all were buried in the sticky asphalt.

The sequence, indeed, had a regular order. First came the thirsty plant eater: mammoth, bison, camel or ground sloth. Wading into the water, in its eagerness to drink, its feet sank into the bottom. Frightened, it struggled to reach the shore, only to mire itself more deeply. Its efforts attracted prowling bands of sabertooth and lion, which pounced upon the expiring body and found themselves also caught. On their heels came wolves, at first warned off by the snarling cats, yet emboldened by the sight and smell of fresh meat. Eventually they plunged in to share in the spoils—and

instead, added to the store of a death trap in which every skeleton became a fossil, preserved in unsurpassed perfection.

Meanwhile, condors soaring from the mountains were attracted by the fight and the dying mammals. They waited till even the wolves expired, and then swooped down to feed on the carcases. Often they gorged themselves and left; but if smaller vultures crowded about them, there was almost sure to be a fight. Birds shoved and beat each other back from the food, and the losers found legs and wings seized by the sticky asphalt, into which they too sank, prey to the forces of hostile nature and their own eagerness for meat.

CHAPTER XVI

APES, MEN AND MAMMOTHS

LATE in the Pliocene, a new animal came to western Europe. He had long legs and an upright body; his short fore limbs ended in hands which clutched sticks, threw stones, or pulled things out of crevices. His head was short, round and shaggy, with teeth of no use for fighting. When bands of these creatures traveled together, they made little noise, as though afraid. At the approach of a saber-tooth or cave bear, they scampered to safety in trees. There they shouted and laughed at their enemy or made special noises to each other, which all seemed to understand. What they called themselves we do not know, but our name for them is Dawn men.

In distant Asia, of the early Miocene, the ancestors of these Dawn men had lived in forests where they journeyed by swinging from tree to tree. Their food was fruits, nuts and insects; their homes were tangled beds of branches. They came down only for occasional play or to pick up fruit that had fallen to earth from twigs beyond reach of their agile arms. Never did they go far from the forests, where lay their sole refuge from enemies. Trees gave both food and safety. In them the apes were glad to stay, if changing nature only permitted.

But changing nature destroyed the forests and sent the apes forth to life on the ground. As the mass of the Himalayas heaved upward, the climate cooled and grew dry. Tropical species became extinct: those that replaced them were too small to shelter the growing ape men, too poor in fruits to provide them with food. On the ground things were a little better, but for the constant threat of hungry carnivores. Reluctantly the ape men descended, to pit luck and wits against savage teeth—to hide or die when they could not run. A few followed the retreating forests into the warm haven of Africa: they, it seems, have remained apes. Many stayed and starved in the hills, or filled the stomachs of wolves and lions: they are unknown even as fossils. Some managed to eat and survive, and they became the fathers of men.

The change did not come in a year or century. Much had to happen ere these desperate primates could hold their own in the fight for life. Legs must grow long, feet must straighten, thighs must twist till they bore the weight of the body without assistance from arms. Wits always keen became still more active, solving the problems of life on the ground, and taking the place of claws or armor. Here hands found a new occupation far more varied than the work of walking, or of swinging the body from tree to tree. Did food hide under water or stones? Hands must manage to pull it out, using sticks to spear what they could not reach or to overturn stones too heavy for lifting. Did it run swiftly when alarmed, or resist mere blows of the fist?

That same fist laid hold of a club, to beat the head of the hardy victim or to hurl upon it as it fled. Growing brains directed these movements, or planned escape at threat of danger. The ape man's mind was both defense and weapon, and his hands the tools by which it triumphed.

The greatest of those triumphs was the taming of fire. Flames were the bane of the dry woodlands, as well as of open, grassy prairies. Many an ape man had fled before them, to find escape in a pond or cave, or to fall exhausted in the path of the blaze. Survivors knew that wolves and lions also ran from fire; that after a conflagration the country was freed of savage carnivores. Yet they knew that it was left without food, so that starvation came when the carcases of victims were rendered inedible by decay. For ages fire was only an enemy—until some one made an astounding discovery:

Big fires were those that did the damage; small ones might burn for days or weeks and still work no harm. Parts of those small fires might be caught, kept and fed, and used for comfort or protection. Put at the mouth of the home cave, they frightened away the bears and lions or even marauding bands of men. Inside, they gave part of their warmth to the damp, cold cavern, and made light after the sun had set. They even could be used to render soft and tasty the flesh of large, coarse-muscled animals.

Thus the great triumph was won—at many times and in many places, by men of varied knowledge and

foresight. From it grew safety and comfort at home, even when chill blasts came from the glaciers which began to creep down the sides of mountains. About the fires, families gathered for warmth; in them, sticks were hardened and pointed to serve as weapons for hunters. With these, larger animals were killed, their skins being turned into robes and clothing as the winters continued cold. When stones came to be shaped, as well as sticks, and traps were devised for killing animals too strong to be felled by weapons, man at last achieved equality with beasts. He was the physical peer of cave bear and lion—with the measureless advantages of an active mind, of tools to be copied and improved by his children, and of a voice trained for the formation of words through which knowledge could be passed to succeeding generations.

Such was man's rise from the man-ape. Much of the story is imagination based on our knowledge of what might have been, and on inference from modern conditions, yet does not consist of these alone. Central Asia was the great breeding ground of mammals, from which they spread into other continents. The Himalayas arose in the late Miocene, and in their foothills are found fossils of manlike apes. At Taungs, South Africa, quarrymen opened a cave filled with bones of extinct animals, among which was the skull of a young ape, with face and teeth almost perfect, and a surprisingly large brain case. It resembles neither chimpanzee nor gorilla, but stands midway between the Miocene apes and the earlier types of fossil man—a missing link

that no longer is missing: the unchanged descendant of one of those anthropoids which began the change from beast to human, but was driven from central Asia, to survive long beyond its time in the warmer, kindlier refuge of Africa.

But what of the men of Pliocene England? They also left fossils, with the skulls of men and the jaws of chimpanzees. Chipped flints seem to show that they made stone weapons, even though they doubtless continued to use fire-hardened spears and war clubs. Thus they were as well armed as their Asiatic relatives, whose discovery is one of the latest and most surprising chapters in the long hunt for our subhuman forebears.

The Western Hills lie some forty miles beyond Peiping or Pekin, ancient but deposed capital of China. From them comes the marble or "white jade" which adorns many a palace and temple, as well as the more prosaic stone from which common lime is made. When a railroad was built to the Hill village of Chou Kou Tien, to tap the rich field of coal near it, the burners of lime saw their chance. Opening large quarries, they sent their product to the city on cars drawn by the new iron dragon and thus scored a point on their business rivals.

Those quarries opened rifts and caves like the one at Taungs, South Africa. Many of them contain fossils which the Chinese call "dragon bones" and sell to the ailing as medicine. In 1919, government scientists began to gather them: from a single cavern, more than four tons of bones have been sent to the national geo-

logical museum of China. There are fragments and even complete skeletons of bats, saber-toothed tigers, hyenas, rhinos, bison, horses, antelope, mammoths and other mammals which lived early in the glacial or Pleistocene period. Some actually made their homes in the cave; others fell in through holes in the roof; many were dragged in by bears and hyenas—or by the primitive men who made the cavern their home.

In 1922, the first human teeth were found, and a third tooth appeared four years later. In 1927, Dr. Davidson Black of the Peking Union Medical College, named this third tooth *Sinanthropus pekinensis,* the "Chinese man of Pekin." The next year brought forth bones of the head, and on December 2, 1929, a Chinese geologist, Dr. W. C. Pei, found an excellent skull cap of Pekin man.

Dr. Pei had worked all summer and on through the fall. But at last he decided to dismiss his workmen, since the weather had grown too cold for digging. Before leaving the pit, he made one last survey—and, digging into a soft layer at one side of the cave, exposed the curved bones of a skull imbedded in lime deposited by seeping waters. Still enclosed in rock, the fossil was removed, wrapped and plastered to prevent damage, even on the short trip to Pekin. There it was delivered to Dr. Black, who began the four-months' task of removing the matrix so that the bones of the skull might be separated for study and the natural cast of the brain exposed.

Later finds have added to these records of the Pekin

race, which now range from a child of eight or nine to a young man and mature woman. They were lowly and unattractive people, with skulls that were thick and bore heavy brow ridges, while their jaws were long, heavy and chinless. More apelike than the Pliocene Englishmen, they still possessed traits prophetic of man.

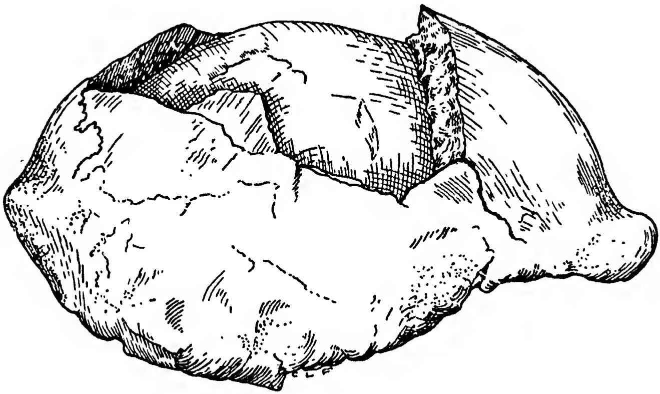

FIG. 33.—SKULL OF PEKIN MAN, SHOWING THE HEAVY BONES AND NATURAL BRAIN CAST. (SMITH)

Perhaps they were survivors of the ancestral group from which the Dawn men had diverged as they traveled toward Europe, and from which the famed Pithecanthropus degenerated during his retreat to Java.

How Sinanthropus lived remains somewhat uncertain. Apparently the cave was his permanent shelter: a layer of charcoal twenty-five feet thick suggests that fires were built day after day for many decades. Around them crouched generations of savages, roasting

meat which they had killed with their few stone weapons, some of which were buried among the ashes. During some of their ceremonies they drank out of bowls made from human skulls—skulls that later would become priceless fossils. But of their daily lives we know little, except that they managed to outwit their enemies and to ward off the beasts that frequented the caverns, or kill others that were needed as food.

Thus they lived long beyond their appropriate evolutionary time, while new and stronger races developed and spread. Hardly had the Dawn men arrived in England when new migrants set forth on their trail. On the way, they survived the first glacial epoch; encouraged by returning warmth, they pushed westward and northward into Germany. There they dwelt during interglacial times, in valleys peopled by elephants, rhinos, hippopotami and saber-toothed cats. Perhaps they achieved real importance, surviving the return of glacial ice and hunting through glades now barren and wind-swept. But if so, they failed to leave adequate records: one jaw and a few bits of bone buried in interglacial gravels are their sole legacy to an imaginative world. From these, we only may sketch the Heidelberg hunter as a stocky fellow, chinless and incapable of human speech. His teeth bear out this impression of a creature too manlike to be an ape, yet too primitive to be a true man—another of those famous "missing links" that no longer is wholly missing.

Though the Heidelberg hunter left few remains, he enjoys the glory of abundant descendants. Or perhaps

we should say evolutionary nephews, for though the famed race of Neanderthal seems to have sprung from the Heidelberg *type,* it did not arise from the man of the gravel bed. Indeed, it is impossible to say where and when the Neanderthal peoples appeared, and each new discovery makes matters less certain. Probably they arose in south central Asia, from ancestors related to the interglacial Germans; but there are some who hold that an early Sinanthropus migrated westward and evolved into the Neanderthaler, while the lowly Pithecanthropus produced similar races in Java. And some authorities confess that they know very little about the matter and will wait for new finds to solve the puzzle.

Whatever their origin may have been, there can be no doubt that human races of the Neanderthal type spread far and wide over the earth, which they ruled for many thousands of years. From Java to western Europe they ranged, and through Palestine into Africa, where some lived long after their extinction elsewhere. They made their homes under overhanging rocks and in caves from which they drove bears, lions and hyenas. Armed with unbounded vigor and strong weapons they overcame the problems of a harsh existence, achieving both abundance and a sufficient security for the development of their own crude culture.

Despite his prowess, the Neanderthaler was not prepossessing. Little more than five feet in height, his thick body always stooped, and he stood or walked with bowed legs and shuffling, bent-knee gait. His large head was thrust forward on a stocky neck; heavy brow

ridges and a receding chin proclaimed his kinship with the apes. He spent much time squatting on his heels in the sun, talking in an uncouth language of grunts, while he and his friends chipped their strong flint weapons. When one of the band died, all gathered to bury him in a grave provided with simple offerings. Perhaps there even was a leader who seemed to know something about the meaning of death, and of future life amid easy hunting in a land reserved for one's own tribesmen.

We may not despise the Neanderthaler, even though he was an ugly savage who dwelt in filth in a dark, damp cavern. He had taken that cave from beasts of prey; he kept it when they sought to return, striking them with spears and hammers so heavy that they crushed even the skull of the cave bear. He also made knives and scrapers so sharp that they can be used to-day, after lying fifty thousand years in the rubbish that gathered about his hearth. Even when glaciers advanced he did not despair, but clung to the shelters of his choice and hunted in valleys choked by ice. For five hundred centuries he dominated Europe at a time when strength, endurance and courage were needed merely to keep alive.

Yet he eventually gave way to new races, whose origins also lie hidden in mystery. Some believe that they arose from, and among, the Neanderthal tribes in the country which to-day is France; others picture them as immigrants from Asia, who made war upon the earlier cave men during the fourth epoch of glacial

retreat. These suppositions are dramatic—but a find in England (the Lloyd skull) seems to indicate that men of modern species reached that country along with the earliest Neanderthalers! To fit this situation, one anthropologist has suggested that *Homo sapiens* actually explored western Europe before the slower cave men arrived, and finding its increasing cold unpleasant, sur-

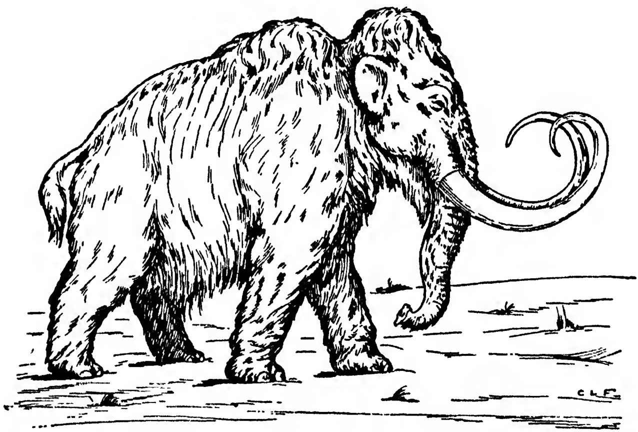

FIG. 34.—THE WOOLLY MAMMOTH OF GLACIAL EUROPE AND ASIA. (OSBORN)

rendered the continent to the less critical Neanderthalers during the final epoch of glaciation. When the ice melted, he again returned to dispossess the established owners and seize their homes for his own.

Be that as it may, this is certain: The Neanderthalers vanished before new and varied races which belonged to our own species of man. Some promptly settled in

caves; others were nomadic hunters; many built villages in the shelter of cliffs, where they lived for generations and centuries. The greatest of these villages was that of Predmost, eighty miles northeast of Vienna: the home of stocky, active hunters whose favorite game was the woolly mammoth.

Though hunters, the men of this village were active and persistent workmen. They made flint knives, scrapers, spears and tools for engraving on bone or ivory. From the ivory itself they cut forks and spoons, spear points and paint boxes. Ribs of mammoths served as polishers and tomahawk handles; daggers were cut from the bones of the lion. At least one warrior carved his war club from the leg bone of a mammoth, while others used balls and cylinders of ivory as weights on skin-rope lassos. They pierced teeth of bears, lions, wolves and hyenas for stringing into charms or necklaces; from a compound of clay and powdered, charred bone they modeled small figures which may have been either fetiches or idols. At feast times, both men and women painted themselves with patterns of red, white and yellow, using colored earth mixed with grease and ground on bone or ivory palettes.

The greatest feasts were on meat of the mammoth, for it was the hunters' largest prize. The mammoth gave food, weapons and the stuff for art; its bones protected the tribe's dead. Yet it was too large to be sought in the open, or killed with spears and axes. For

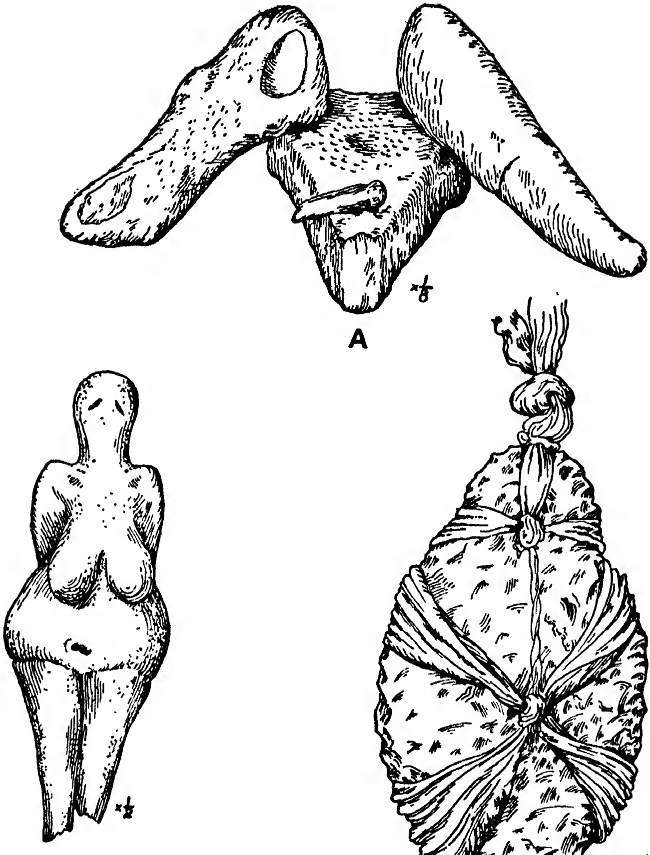

FIG. 35.—RELICS FROM THE VILLAGE OF MAMMOTH HUNTERS.

A, stone anvil and three hammers; B, figure of a woman modeled in clay and crushed bone; C, a "maul" for killing mammoths, showing how it probably was tied with rawhide. (Absolon)

its capture, deep holes were dug and set with sharp stakes, to be hidden by a flimsy layer of branches. Each pit lay beneath a tall tree: when scouts brought word that a mammoth was trapped, the men set forth with long coils of skin-rope, dragging a massive pear-shaped stone. Arriving, they lashed the rope to the stone, carried the free end over a branch and pulled lustily upon it. Slowly the huge rock arose, while the entrapped mammoth thrashed and trumpeted. At a word from the leader, the men let go—and the stone crashed down on the helpless beast, like the hammer of a simple pile driver. Not many such blows were needed ere the huge carcass lay still. Men began to cut it to pieces, while the whole band set themselves to the task of carrying or dragging home portions of their capture.

Then came the great feast of mammoth meat. The skull was broken to secure its brain; bones were split for their marrow. Chunks of meat were roasted over open fires, while hunters sang and danced, or boasted of future and greater kills. At last the gorged, tired tribesmen rested while hyenas crept up in the shadows, anxious to get their share of offal.

Yet these first true men of Europe were not mere butchers and gluttons. In the leisure procured by their skill in hunting, they made tools of beauty as well as use, carved graceful ornaments and engraved strong, if simple pictures upon plaques of bone and ivory. In their tough savage minds was that urge toward art which would lead their successors in western Europe

to cover cave walls with painted bison and mammoths, and to model beasts in damp clay. Man at last had won the chance to dream, and his dreams turned to things of beauty.

CHAPTER XVII

CAN THESE BONES LIVE?

THE rest of the story we already know. Though the mammoth hunters prospered greatly, they gave way to other races. Men who filled caves with vigorous paintings weakened and fell before crude invaders. New races surged to and fro, bringing both life and destruction with them, since they mingled with peoples whom they conquered. In time, they learned to polish stone weapons; others replaced stone with metal. From copper and iron they turned to alloys, and with arms and armor thus perfected, set out on further journeys of conquest. Those journeys still continue, with new and still more insidious weapons. Races fight to dispossess races, yet absorb blood from those that are vanquished.

But has all this struggle and shifting meant progress, if racial life is our measure of value? Are modern men more persistent or sturdy than the bent-kneed Neanderthaler? Are their brains more active than those of the tribesmen who with crude arms hunted the mammoth? And what of the future of man's body, in a world whose record is one of extinctions?

One is bound to ask himself these questions as he surveys the vast array of fossils. In its time, each of

these creatures seemed good: each held the promise of successful existence. Yet all but a few became extinct, and extinction often followed close upon what appears to us as their greatest achievement. Trilobites, cephalopods, dinosaurs and Dinoceras—these and countless others began to decline, even as they seemed to prosper. Man himself has been part of this series, destroying and replacing other animals, even of his own favored species—and in turn he has been destroyed.

In this endless generation and extinction, are we to read a story of purposive progress? Perhaps: yet in so doing we set ourselves as a goal and sanctify our own desires as good. Was it progress when fishes produced amphibians, when reptiles gave way to archaic mammals? Yes, if warm blood is better than cold—if life on land surpasses that in the water. Eryops walked and fishes didn't; creodonts grew fat where Tyrannosaurus would have starved. Yet Eryops vanished during the Permian, while sharks and lungfish survive to-day. Were racial survival our measure of goodness, we should give first place to Lingula or the king crab, whose lives measure hundreds of millions of years.

But should we not judge by affairs of the intellect, or capacity to make use of the earth? Granted: but was nothing lost by the extinction of peoples as skilled as the mammoth hunters of Predmost, as intelligent as the French cave men? Man's rise has involved much forgetting: the modern scientist puzzles and labors to regain bits of the routine knowledge which belonged

to every Stone Age hunter. In spite of this man has learned—yet even his most precious civilization displays trends harmful to spirit and body, and rests upon wanton, world-wide destruction, on reckless use of nature's resources. If a super-beast were given to philosophy, he would rank the coming of the genus *Homo* as the greatest and most irrational disaster that a long-suffering earth has sustained. Only insects and germs have profited by it; and they, like man, are greedy destroyers.

Such is our prized organic progress: a series of origins, rises and declines whose end often has been destruction. Standing at the crest of a wave of dominance such as no other species has known, we view the means of our coming as good and ourselves as the goal of evolution. Perhaps we are, for man has such power to kill that few animals may oppose him. Even a new and more competent humanity would be wiped out as it began existence, should it do so in a way contrary to our customs and wishes. In this power to destroy lies man's chief guaranty of a future. Let it decrease or become too highly developed, and he will be confronted by organisms more experienced in the ways of the earth than he, ready to contest his rule of the land. Probably they will not be able to supplant him, but they will mar the bland armor of his ego and make the course of evolution seem less obviously good. Amid vanishing glory man may go even further, and denounce it as hopeless or evil.

Yet despair will come no nearer truth than does the

present optimism of conceit. Evolution is a process, not an agent: its ways can be neither good nor bad. Stripped of human prejudice and desire, it presents imposing yet unconscious indifference to accepted standards of purpose or value. Its one great result is change, and change may bring either plenty or peril. New habits and structures may insure success, especially if the earth's surface is changing. They may result, however, in swift extinction, while forms survive whose most striking virtue is the stubborn retention of primitive structure. The most prosperous things on the face of the earth are minute plants that live in sea water. Their tiny bodies are unicellular, and they do not even gather in chains.

Evolution thus betrays no purpose, as purpose is known to the human mind. It does accomplish organic change: the production of new structures or species from others of more primitive kind. If we wish, we may call such changes progressive, be their product a rose or a degenerate tapeworm. They have brought fitness to many organisms, in many and varied times and places, and in ways we do not often approve. But as ages passed that fitness declined, and decline often ended in extinction. There are countless thousands of living species; yet few are more than a million years old, while many are a great deal younger. That the age of life far exceeds a billion years is some measure of the deaths that have occurred.

What does this mean for humanity's future? Will man avoid the fate of extinction, or will his bones

join those of Baluchitherium as the records of a dead and forgotten Titan?

Such questions are hard to answer, except on grounds of prejudice or desire. Most of us wish to see man continue, much as we lament his present faults. Yet honesty compels the admission that desire may mean as little in human survival as it meant in that of titanotheres. In the cycle of life there seem to be factors which bring decline almost as surely as rain makes rivers. Species vanish in the midst of plenty which their ancestors found highly favorable. Mammals have long since passed their zenith; to-day they form a diminishing race whose fate may be shared by their prodigal, man. His intelligence doubtless will prolong the struggle by enabling him to kill organic enemies or to build artificial conditions more tolerant of his needs than are those of nature. Man has gone far on this path already: in the thousands of centuries that lie before him, he is bound to achieve what we deem miracles. Ages of success will be his—yet the course of life will cease to hold if his species, at least, does not die.

Yet, even should we grant what seems impossible, a limit already is set. Man may transcend organic compulsions: he cannot guide and remake the world. Unless our conception of the universe is wholly false, the solar system is running down. A time must come when the sun will stop shining—when earth's only light will come from the stars. Life, shorn of its energy, will vanish, and such creatures as men will be

first to go. In that distant time, he whom we imagine to have transcended evolution will meet an enemy that he cannot conquer. Bones still will record his existence, but they will not be the bones of living men.

CHAPTER XVIII

THE STUDY OF FOSSILS

PALEONTOLOGY, like many another science, began among the ancient Greeks. Xenophanes, in the sixth century B.C., recognized fossils as records of life, and from the presence of marine remains upon land drew support for his idea that water was the substance from which earth emerged. Aristotle also knew something of the meaning of fossils, but the majority of Greeks would not accept his knowledge. For them, petrified bones were the remains of dwarfs and giants; shells, mere freaks or "sports of nature"—or the products of mystic creative forces that had labored deep within the earth and had failed to bring their creations to life.

These theories appealed also to the Arabs, who passed them on to medieval Europe. There, fossils also were transformed into relics of famous saints, or the skeletons of drowned pre-Noachian sinners. Yet by the close of the fifteenth century the abundant specimens of the Italian stone quarries had begun to excite scientific inquiry. Leonardo da Vinci paused from his art to announce that shells and teeth in the rocks of the Apennines proved the one-time presence of sea; Nicolaus Steno, a professor at Padua, compared the

structures of fossil and living animals. Martin Lister, an English physician, followed him even while clinging to the outworn idea that fossils were mere sports of nature. But another Englishman, Robert Hooke (1635-1703), drew from fossils the theory of extinction of races and surmised that they also marked the ages of rocks and recorded major changes of climate. Fifty years after Hooke's death, the Italian, Soldani, distinguished fossils of the deep sea from those of the shore, while Buffon, pioneer French evolutionist, announced that the lands often had submerged and uplifted.

Thus the groundwork of paleontology was laid, chiefly before 1770; upon it a structure of discovery was built by zoölogical systematists and travelers. Linnæus (1707-1778) gathered fossils on his collecting journeys; Pallas discovered the "graveyards" of mammoths while exploring Siberia in 1768-1774. In 1793, Thomas Pennant named the mastodon *Elephas americanus,* the name *primigenius* already having been given to the woolly mammoth. A few years later, the evolutionist Lamarck began the studies of marine invertebrates of the Paris basin, which were to establish the systematic methods of paleontology, at least as applied to boneless animals.

For the vertebrates, a similar service was performed by Lamarck's enemy, Cuvier—also using fossils uncovered near Paris. Unfortunately, he could see nothing in the bones of Eocene mammals which gave the slightest hint of evolution, and so proposed the theory

that life was a series of prosperous epochs terminated by catastrophic extinctions. After each catastrophe, the continents were repopulated by migration from "unknown regions," and by new acts of divine creation. The "unknown regions" still remain popular—consider the rôle of central Asia in the evolution of man—but creations have lost scientific repute. Partly this must be credited to Darwin; yet much responsibility rests upon Cuvier's admirer, Alcide d'Orbigny, who carried his master's doctrine so far that it became absurd. Twenty-seven world-wide creations were too many, even for creationists—and besides, the German Bronn had shown that species sometimes did survive from one epoch to another, despite d'Orbigny's denials.

While speculators thus disputed, paleontology continued to grow. In 1801, William Smith had begun to distinguish the Mesozoic rocks of England by means of their fossils: his methods soon were applied throughout Europe. Other workers undertook to describe the extinct faunas of regions or kingdoms—Goldfuss in Germany, Barrande in Bohemia, Deshayes in the Paris basin.

Interest meanwhile spread to North America. In 1817, Amos Eaton tramped through New York and New England collecting rocks, minerals and fossils, and lecturing on paleontology. Ten years later, he was head professor at a school in Troy founded by the Patroon van Rensselaer, and was announcing geologic courses and field trips. One of his students was a lad named Hall, who in 1837 became one of New York's

four state geologists. Some thought him too young for the job: but in 1843 he published a quarto report which set a standard in American science and made its author a world figure. For fifty years, James Hall dominated American paleontology, training most of its workers, and publishing thousands of plates and pages. The thirteen quarto volumes of the *Palæontology of New-York* are but part of the labors of Hall and his assistants, yet they give some measure of their achievement.

As official exploration progressed, paleontology moved westward. In 1840, David Dale Owen published his first report on rocks and fossils of the Mississippi Valley; seven years later appeared Joseph Leidy's first account of American fossil horses. For some years, Leidy described the vertebrate fossils collected by government expeditions, but that work gradually was taken over by E. D. Cope, of Philadelphia, and O. C. Marsh, of Yale. The rivalry of these men in their efforts to collect and describe the dinosaurs, titanotheres and other vertebrates of the West forms a tumultuous chapter in American science.

Yet, thanks to the efforts of its leaders, paleontology became too broad a field for dominion by two or three men. With or without Hall's approval, his assistants went to other museums and surveys; Marsh's ablest aides left him to become authors in their own right. Whitfield, Meek, Walcott, Schuchert, Dall—these and many others described invertebrate fossils, while the names of Williston, Scott, Lull and Osborn appeared

on articles devoted to vertebrates. The science had passed its heroic period and had entered one of specialization, in which many workers made their detailed inquiries and by their numbers as well as the quality of their efforts discouraged individual attention and praise.

To survey the modern science of fossils, we must turn from individuals to schools. One of these, especially developed in America, has found fossils of value in commercial geology. Following the advice of Robert Hooke, they study invertebrate genera and species as markers of significant formations, thereby recognizing beds that contain petroleum and other valuable substances. Another group use fossils to determine the wanderings of animals and plants, and to check geologic records of earth evolution; from their labors maps like that of Figure 6 are derived. Still others seek long series of petrified remains for successive stages in organic change, and hints of the processes by which one kind of creature develops from another. Here leadership is divided between North America and Europe, though English and German students are inclined to stress invertebrate lineages, and those of America the mammals. No such distinction can be made, however, among those who seek to describe and name the new kinds of fossils that are being discovered every year. Faced with an endless array of unrecorded species, all do their best to reduce apparent chaos to an orderly system of genera and species. If they fail to keep up, the fault is not theirs:

the earth has produced more things in its billion years than man can hope to name in less than two centuries.

Finally, we come to those who deal with fossil men. Here scientists of the Old World have an obvious advantage: it is on their soil that most finds have been made. Thus we find that French scientists, such as Boule and Breuil (of the Institute of Human Paleontology, Paris), lead in studies on the cave men of France; while Catedratico Obermaier, when forced to Madrid from Paris at the outset of the World War, devoted his attention to fossil men of Spain. A Dutch surgeon, DuBois, found Pithecanthropus in Java, and one of his countrymen, Dr. Oppenoorth, has charge of the survey which discovered the Solo skulls. Yet there also is abundant internationalism: Pekin man was found by a Chinese geologist and described by an English professor financed by American grants. Few paleontologists to-day attempt to follow the example of Marsh and James Hall, who selected states and subjects as their special preserves which intruders might enter only at peril. Recovery of the story of prehistoric man depends too much on coöperative efforts for this policy of exclusion to find much favor.

But who supports the study of fossils? In early days, the work was done by enthusiastic professors, by curators in state or national museums, and by amateurs ranging from quarrymen to clergy who found joy in strange petrifactions. Soon they received important reënforcements—the staffs of government surveys and exploring expeditions sent out to examine unfamiliar

countries, or to learn more of those already known. Charles Darwin was a member of such an expedition when he discovered the fossils of Patagonia; as a geologist for the state of New York, Hall did the work that made him famous and established paleontology in North America. As decades passed, such surveys grew until to-day they form elaborate organizations with thousands upon thousands of volumes to their credit—many of them devoted to fossils.

Meanwhile, industry was turning to science for aid in procuring the minerals that were needed for manufacture. For a long time, they were content to hire geologists and leave the paleontologic work to men paid by colleges, surveys or museums. Yet for oil, at least, this plan did not work: the geologists who were tracing productive formations demanded prompt analysis of fossils from them, in a form suited to their special needs. Thus appeared economic paleontology—the study of fossils found in oil drillings by scientists employed by the producing companies. The amount of work that these men have done is immense, yet it is largely confined to Cenozoic shells and organisms so small that they may be found abundantly even in drill cores. Fish, cephalopods, dinosaurs and trilobites are too large to be thus represented, and often too rare to help much if they were not.

Yet this does not diminish their interest. Like mammals and mosasaurs, they deserve careful study—not because they promise profits, but because they record chapters in the history of life, a history we deem worth

learning. For these parts of it we must turn to the successors of the pioneers: professors and museum investigators whose business it is to acquire knowledge without regard for utility or dividends. That they respond freely, this book, based as it is upon their researches, forms sincere if not adequate testimony.

REFERENCES AND COLLECTIONS

Fossil hunters often are too busy to write much about their experiences and methods. Yet C. H. Sternberg's *Life of a Fossil Hunter* (New York, 1909; Los Angeles, 1930) gives an excellent biography of a pioneer collector in North America. There also are articles on fossil collecting in *Natural History,* especially Volume 26 (1926), pages 440-544. W. D. Matthew describes work in Nebraska in the same journal, Volume 23 (1923), pages 359-369; while an account of dinosaur hunting in Canada, by Barnum Brown, is found in the *National Geographic Magazine,* Volume 35 (1919), pages 408-429.

The Cambrian rocks of Alberta and British Columbia are briefly described by C. D. Walcott in the *National Geographic Magazine,* Volume 22 (1911), pages 509-521. He also gives a brief account of very early fossils in the *Annual Report of the Smithsonian Institution* for 1915, pages 235-255.

Technical discussions of the Cambrian faunas are to be found in Volumes 53, 57, 64, 67 and 75 of the *Smithsonian Miscellaneous Collections,* published by the Smithsonian Institution of Washington.

One of the best accounts of invertebrate fossils and the rocks containing them is the *Handbook of Paleontology for Beginners and Amateurs,* by Winifred Goldring, Handbooks 9 and 10 of the New York State Museum (Albany, 1929 and 1931).

Discussions of trilobites and cephalopods are given by E. W. Berry in his *Paleontology* (New York, 1929) and in R. S. Lull's *Organic Evolution* (New York, 1931).

The most useful book on fossil fishes is Dean's *Fishes Living and Fossil* (New York, 1895), though Lull, Goldring and Berry discuss these animals, and they are given a chapter in J. R. Norman's *History of Fishes* (New York, 1931).

Permian amphibians and reptiles are described in technical papers by Case, Broom, Williston and others; but one may prefer to read articles by E. C. Case (*Popular Science Monthly,* Volume 73, 1908, pages 557-568) and S. W. Williston (*Journal of Geology,* Volume 22, 1914, pages 57-70) which are less detailed.

Dinosaurs are discussed by Lull in the book already mentioned; on pages 81-113 of *Animals of the Past,* by F. A. Lucas (Sixth edition: New York, 1922), and in *Dinosaurs,* by W. D. Matthew (New York, 1915). H. G. Seeley's *Dragons of the Air* (London, 1901) contains a general account of pterodactyls, which also are treated in the volume by Lucas.

Water Reptiles of the Past and Present, by S. W. Williston (Chicago, 1914) is a non-technical summary which still gives some attention to skeletons. G. Heilmann's *Origin of Birds* (New York, 1927) is a standard work, though some dislike its restorations.

There are many accounts of fossil mammals. Lull deals with them in *Organic Evolution;* W. B. Scott's *History of Land Mammals of the Western Hemisphere* (New York, 1913) is non-technical and abundantly illustrated. The reader who wants to see how imposing a monograph on fossils may be, should glance at H. F. Osborn's *Ti-*

tanotheres of Ancient Wyoming, Dakota and Nebraska (Monograph 55, U. S. Geological Survey: 2 volumes, Washington, 1929); but unless a paleontologist, he will derive more information from papers of less technical nature scattered through the volumes of *Natural History.*

Chester Stock's volume on ground sloths (Carnegie Institution of Washington, Publication 331, 1925) and his *Rancho La Brea, A Record of Pleistocene Life in California* (Los Angeles, 1930) expand the brief chapter on glacial animals in this volume. John C. Merriam collaborated with Stock in the production of a monumental book, *The Felidae of Rancho La Brea* (Carnegie Institution of Washington, Publication 442, 1932). Those who suspect that man lived in early America also should read Stock's paper on the remains of Gypsum cave, in the *Scientific Monthly,* Volume 32 (1931), pages 22-32.

Discussions of fossil man are—and should be—endless. *Men of the Old Stone Age,* by H. F. Osborn (New York, 1915 and later) is on most library shelves. More recent and general is E. A. Hooton's *Up from the Ape* (New York, 1931)—a book, by the way, which attacks the theory that man first appeared in Asia.

Skeletal Remains of Early Man, by Aleš Hrdlička (Smithsonian Miscellaneous Collections, Volume 83, 1930) is a detailed account of man up to the level of Neanderthaler, who Dr. Hrdlička believes is our direct ancestor. It was written too early to include skulls of *Sinanthropus,* of which original accounts are in publications of the Geological Survey of China, as well as some of the other recent finds. A convenient summary by G. Elliot Smith may be found on pages 193-211 of Volume

33 (1931) of the *Scientific Monthly*. Since the study still is in progress, new publications are to be looked for.

There are many collections of fossils, exhibited by museums. The best displays of early invertebrates are in the United States National Museum at Washington and the New York State Museum, at Albany. The world's richest display of dinosaurs is shown by the American Museum of Natural History, New York, though there are remarkably fine skeletons in the Royal Ontario Museum, Toronto, and the United States National Museum. The Carnegie Museum of Pittsburgh, the National Museum of Canada (Ottawa) and the Peabody Museum of Yale University also have important dinosaur exhibits. The first of these has a fine array of Miocene mammals, as does the University of Nebraska Museum, at Lincoln. The Los Angeles Museum of Science and Art has specialized on beasts of the La Brea tar pits, while the Cleveland Museum of Natural History (which went fossil-hunting with a steam shovel) has a remarkable set of Devonian fishes.

Many other public and university museums have worthwhile exhibits, often changed so rapidly that no effort can be made to list them. The best course is to visit them and inquire; such inquiry often will bring aid and information that no tour through halls can procure.

GLOSSARY

Unlike a great many English words, the majority of scientific names are pronounced just as they are spelled. Yet because they often are unfamiliar, these notes may be of help.

Allosaurus (*Al″ lo saw′ rus*). A large carnivorous dinosaur (Saurischian) of Jurassic age.

Alticamelus (*Al″ ti ca me′ lus*). A very tall Miocene camel.

Amblypoda (*Am blip′ o da*). A group of herbivorous archaic mammals.

Ammonites (*Am′ mo nites*). Extinct cephalopods with coiled shells and complex sutures, abundant during Mesozoic times.

Ankylosaurus (*An ky″ lo saw′ rus*). A heavily armored Cretaceous dinosaur of Alberta. One of the Ornithischia.

Archæornis (*Ar″ kee or′ nis*). A toothed bird of Jurassic Europe.

Archeozoic (*Ar″ kee o zo′ ik*). The oldest known geologic era.

Baluchitherium (*Ba lu″ chi the′ ri um*). A huge Miocene rhinoceros of Asia.

Belemnite (*Bel′ em nite*). A squid-like animal of the Mesozoic seas.

Bothriolepis (*Both" ri ol ay' pis*). A Devonian ostracoderm of North America.

Brachiopod (*Brack' i o pod*). Shelled marine animals, abundant in Paleozoic times, but much less common to-day.

Brontosaurus (*Bron" to saw' rus*). A large Jurassic herbivorous dinosaur, member of the Saurischia.

Cacops (*Cay' cops*). A short-tailed Permian amphibian of Texas.

Cambrian (*Kam' bri an*). The first period of the Paleozoic era.

Carboniferous (*Kar" bon if' er us*). A late Paleozoic period, known for the wealth of its coal beds.

Cenozoic (*Se" no zo' ik*). The fifth geologic era, often called the Age of Reptiles.

Cephalaspis (*Sef" a las' pis*). A Devonian ostracoderm of Scotland.

Cephalopod (*Sef" a lo pod*). A marine mollusc, member of the class which includes squids, cuttlefish, ammonites, etc.

Ceratopsia (*Ser' a top' si a*). Horned, carnivorous dinosaurs.

Coryphodon (*Ko rif' o don*). An archaic mammal of North America, resembling a pigmy hippopotamus.

Cretaceous (*Kre ta' shus*). The last period of the Mesozoic era, often called the Chalk Age.

Cynodontia (*Sy" no dont' i a*). Permian reptiles whose teeth and jaws resemble those of mammals.

Cynognathus (*Sy" no gnath' us*). A South African cynodont reptile.

Devonian (*De vo' ni an*). A Paleozoic period in which land forests became prominent and fishes common.

Diceratherium (*Dy" ser a the' ri um*). A small Miocene rhinoceros.

Dimetrodon (*Dy met" ro don'*). A large, carnivorous Permian reptile whose back bore a finlike structure.

Dimorphodon (*Dy morf" o don'*). A long-tailed pterodactyl of Europe.

Dinoceras (*Dy nos' er as*). A six-horned archaic mammal of the Eocene.

Dinohyus (*Dy" no hy' us*). A Miocene elothere or "giant pig."

Dinosaur (*Dy' no sawr*). Reptile belonging to one of two orders (Ornithischia and Saurischia) which achieved abundance and great size during the Mesozoic era.

Dinotherium (*Dy" no thee' ri um*). An elephant-like mammal with tusks on its lower jaw.

Diplocaulus (*Dip" lo caw' lus*). A Permian amphibian with very large skull.

Edaphosaurus (*Ee daf" o saw' rus*). An herbivorous finbacked reptile (Permian).

Elothere (*Ee' lo theer*). A piglike Tertiary mammal.

Eocene (*Ee' o seen*). An early epoch of the Tertiary period.

Eohippus (*Ee" o hip' us*). A small Eocene ancestor of the horse.

Eryops (*Air' i ops*). A large, long-tailed Permian amphibian.

Ichthyornis (*Ik" thi or' nis*). A toothed bird of the Cretaceous.

Ichthyosaur (*Ik' thi o sawr*). A mesozoic marine reptile shaped like sharks.

Jurassic (*Ju ras' ik*). Second period of the Mesozoic era.

Lingula (*Ling' gu la*). A primitive brachiopod, still common.

Lituites (*Lit" u i' teez*). A Silurian cephalopod whose shell became straight in old age, though coiled during youth.

Machærodus (*Ma kee' ro dus*). One of the saber-toothed cats.

Mastodon (*Mass' toe don*). A more primitive relative of the elephant.

Megalonyx (*Meg" a lon' ix*). A Pleistocene ground sloth.

Mesozoic (*Mess" o zo' ic*). The fourth geologic era: the "Age of Reptiles."

Moropus (*Mo' ro pus*). A clawed herbivore of late Tertiary age.

Mosasaur (*Mo' sa sawr*). A marine reptile of the Mesozoic.

Nautilus (*Naw' til us*). A coiled cephalopod, still found in the seas.

Neolenus (*Nee" o lee' nus*). A well-known Cambrian trilobite of Canada.

Oligocene (*Ol' i go seen*). Third epoch in the Age of Mammals, or Tertiary.

Ordovician (*Or" doe vish' un*). An early Paleozoic period.

Oreodont (*O′ re o dont*). An herbivorous Tertiary mammal, often very abundant.

Ornithischia (*Or″ ni thiss′ ki a*). One order of dinosaurs; includes Triceratops and Paleoscincus.

Orthoceras (*Or thos′ er as*). A cephalopod with a long, straight shell.

Ostracoderm (*Os trac′ o derm*). An armored, fishlike animal of the Paleozoic.

Paleocene (*Pay″ le o seen′*). The first epoch of Tertiary times.

Paleontology (*Pay″ le on tol′ o ji*). The science of fossils.

Paleoscincus (*Pay″ le o skink′ us*). A heavily armored Ornithischid dinosaur of the late Cretaceous.

Paleozoic (*Pay″ le o zo′ ik*). The third geologic era.

Permian (*Per′ mi an*). The last period of the Paleozoic era.

Phenacodus (*Fe nak′ o dus*). An archaic mammal of Eocene age.

Phytosaur (*Fy′ to sawr*). A Mesozoic reptile resembling the crocodile.

Pleistocene (*Plice′ toe seen*). The last "ice age" or glacial period.

Plesiosaur (*Plee″ si o sawr′*). A long-necked marine reptile of the Mesozoic era.

Pliocene (*Ply′ o seen*). The last epoch of the Tertiary period.

Portheus (*Por′ thee us*). A large, toothed Cretaceous fish.

Proterozoic (*Pro″ ter o zo′ ik*). The second geologic era.

Pterichthys (*Ter ik' this*). A small Devonian ostracoderm.

Pterodactylus (*Ter" o dak' ti lus*). A short-tailed, winged reptile of Jurassic Europe; one of the *pterodactyls.*

Quaternary (*Kwa ter' na ri*). The division of geologic time which includes the Pleistocene and Recent periods.

Rhyticeras (*Ry tiss' er as*). A frilled Devonian cephalopod.

Saurischia (*Saw ris' ki a*). An order of dinosaurs which includes the largest herbivores and carnivores. See page 70.

Seymouria (*See more' i a*). The most primitive known reptile (Permian).

Silurian (*Si lu' ri an*). A middle Paleozoic period.

Sinanthropus (*Sin an' throp us*). The technical name of Pekin man.

Stegosaurus (*Steg" o sawr' us*). An armored Jurassic dinosaur.

Terataspis (*Terr" a tas' pis*). A large, spiny Devonian trilobite.

Tertiary (*Ter' shi air ri*). The chief period of the Cenozoic era.

Titanothere (*Ty tan' o theer*). A large, horned Tertiary mammal.

Torosaurus (*Toe" ro saw' rus*). A horned Cretaceous dinosaur with a very large skull.

Triassic (*Try as' sick*). First period of the Mesozoic era.

Triceratops (*Try ser' a tops*). A late Cretaceous horned dinosaur.

Trilobite (*Try' lob ite*). A marine animal of the Paleozoic, related to the lobster and king crab, but more primitive than either.

Trilophodon (*Try loaf' o don*). An elephant-like mammal with long, tusk-bearing lower jaws.

Tyrannosaurus (*Ty ran" o saw' rus*). The largest carnivorous dinosaur (Saurischian), of Cretaceous age.

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